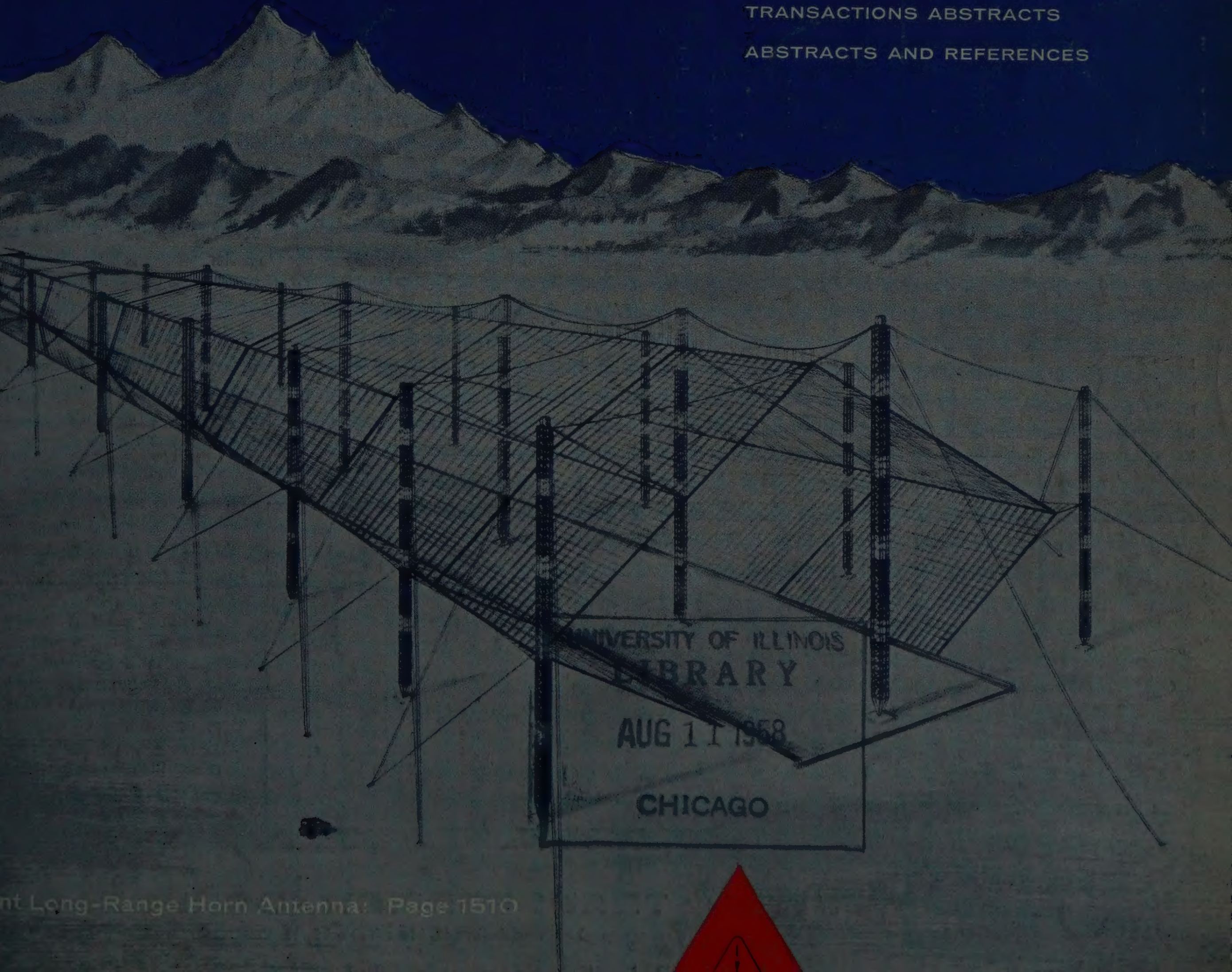
august 1958
the
institute
of
radio
engineers

Proceedings of the IRE

in this issue

- REVIEW OF BATTERIES
- RESNATRON 200 MC POWER AMPLIFIER
- ATMOSPHERIC EFFECTS ON PROPAGATION
- NOISE INTERFERENCE TO BROADCASTING
- DIRECTIONAL HF ANTENNAS
- NOISE PERFORMANCE OF AMPLIFIERS
- TRANSACTIONS ABSTRACTS
- ABSTRACTS AND REFERENCES

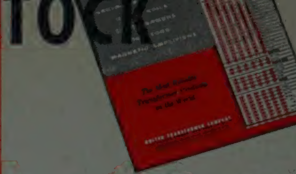


UNIVERSITY OF ILLINOIS
LIBRARY
AUG 11 1958
CHICAGO

nt Long-Range Horn Antenna: Page 1510

Hi-Q Inductors . . . . FROM STOCK

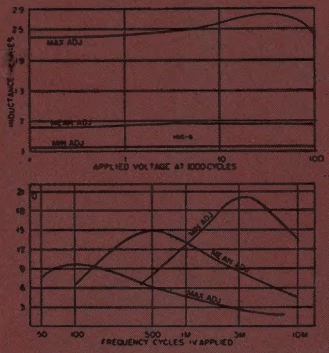
As largest producers in this field for over two decades, UTC inductors cover virtually every need for both fixed and variable units of exceptional stability. Hermetic units have been proved to MIL-T-27A, eliminating costs and delays of initial MIL-T-27A testing.



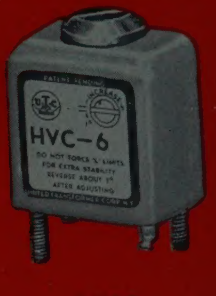
For complete listing of our 700 stock items (300 hermetic) write for catalog.

HVC Hermetic Variable Inductors

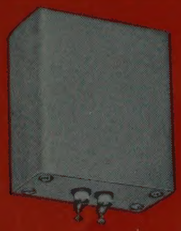
A step forward from our long established VIC series. Hermetically sealed to MIL-T-27A...extremely compact...wider inductance range...higher Q...lower and higher frequencies...superior voltage and temperature stability. Case 25/32 x 1⅛ x 1 7/32, 2 oz.



Type No.	Min. Hys.	Mean Hys.	Max. Hys.
HVC-1	.002	.006	.02
HVC-2	.005	.015	.05
HVC-3	.011	.040	.11
HVC-4	.03	.1	.3
HVC-5	.07	.25	.7
HVC-6	.2	.6	2
HVC-7	.5	1.5	5
HVC-8	1.1	4.0	11
HVC-9	3.0	10	30
HVC-10	7.0	25	70
HVC-11	20	60	200
HVC-12	50	150	500

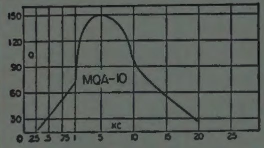


HVC

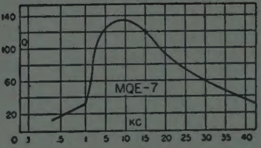


MQ drawn case structure

	Length	Width	Height	Oz.
MQE	1/2	1-1/16	1-7/32	1.5
MQA, MQD	11/16	1-9/32	1-23/32	4
MQB	1-5/16	2-9/16	2-13/16	14

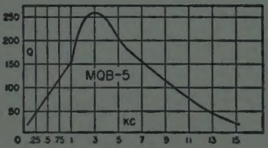


MQA
19 stock values
from 7 Mhy.
to 22 Hy.



MQE
15 stock values
from 7 Mhy.
to 2.8 Hy.

MQB
12 stock values
from 10 Mhy.
to 25 Hy.



MQD

New extreme stability inductors for 12KC to 130KC range. Typical Q is 170 @ 50KC. 6 stock values from 2 mhy. to 20 mhy.

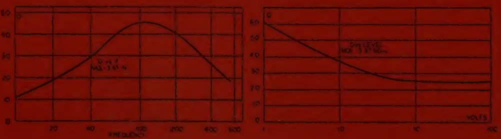
MQ Series Compact Hermetic Toroid Inductors

The MQ permalloy dust toroids combine the highest Q in their class with minimum size. Stability is excellent under varying voltage, temperature, frequency and vibration conditions. High permeability case plus uniform winding affords shielding of approximately 80 db.

MQL Low Frequency High Q Coils

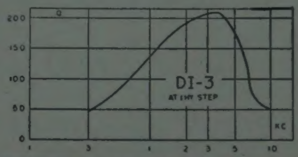
The MQL series of high Q coils employ special laminated Hipermalloy cores to provide very high Q at low frequencies with exceptional stability for changes of voltage, frequency and temperature. Two identical windings permit series, parallel, or transformer type conections. 1-13/16 dia. x 2½" H.

MQL-0	.25/1 Hys.
MQL-1	2.5/10 Hys.
MQL-2	5/20 Hys.
MQL-3	50/200 Hys.
MQL-4	100/400 Hys.
MQL-5	625/2500 Hys.



DI Inductance Decades

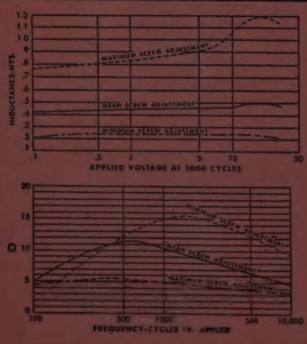
These decades set new standards of Q, stability, frequency range and convenience. Inductance values laboratory adjusted to better than 1%. Units housed in a compact die cast case with sloping panel ideal for laboratory use . . . 4½ x 4⅜ x 2⅜ high.



DI-1	Ten 10 Mhy. steps.
DI-2	Ten 100 Mhy. steps.
DI-3	Ten 1 Hy. steps.
DI-4	Ten 10 Hy. steps.

VIC case structure

Length	Width	Height	Oz.
1-1/4	1-11/32	1-7/16	5-1/2



Type	Mean Hys.	Type	Mean Hys.
VIC-1	.0085	VIC-12	1.3
VIC-2	.013	VIC-13	2.2
VIC-3	.021	VIC-14	3.4
VIC-4	.034	VIC-15	5.4
VIC-5	.053	VIC-16	8.5
VIC-6	.084	VIC-17	13.
VIC-7	.13	VIC-18	21.
VIC-8	.21	VIC-19	33.
VIC-9	.34	VIC-20	52.
VIC-10	.54	VIC-21	83.
VIC-11	.85	VIC-22	130.

VIC Variable Inductors

The VIC Inductors have represented an ideal solution to the problem of tuned audio circuits. A set screw in the side of the case permits adjustment of the inductance from +85% to –45% of the mean value. Setting is positive.

Curves shown indicate effective Q and L with varying frequency and applied AC voltage.

SPECIAL UNITS TO YOUR NEEDS
Send your specifications for prices.

UNITED TRANSFORMER CORPORATIO

150 Varick Street, New York 13, N. Y.

PACIFIC MFG. DIVISION: 4008 W. JEFFERSON BLVD., LOS ANGELES 16, CALIF.

VOLUME 46, NUMBER 8

August, 1958

published monthly by The Institute of Radio Engineers, Inc.

Proceedings of the IRE©

contents

Poles and Zeros **1459**

Glenn A. Fowler, Director, 1958-1959 ..... **1460**

Scanning the Issue **1461**

PAPERS

Batteries, *C. K. Morehouse, R. Glicksman, and G. S. Lozier* **1462**

The Resnatron as a 200-MC Power Amplifier, *E. B. Tucker, H. J. Schulte, E. A. Day, and E. E. Lampi* **1483**

Atmospheric Effects on VHF and UHF Propagation, *George H. Millman* **1492**

Atmospheric Noise Interference to Medium Wave Broadcasting, *S. V. Chandrashekhar Aiya* .. **1502**

Suppression of Undesired Radiation of Directional HF Antennas and Associated Feed Lines, *H. Brueckmann* **1510**

Optimum Noise Performance of Linear Amplifiers, *H. A. Haus and R. B. Adler* **1517**

Correction to "Recombination in Semiconductors," *G. Bemski* **1533**

CORRESPONDENCE

Observations of the U. S. Satellites Explorers I and III by CW Reflection, *J. D. Kraus, R. C. Higgy, and J. S. Albus* **1534**

WWV Standard Frequency Transmissions, *W. D. George* **1534**

Continuous Phase Difference Measurements of Earth Satellites, *J. W. Herbstreit and M. C. Thompson, Jr.* **1535**

Semiconductor *P-N* Junction Radiation Counter, *B. Salzberg and K. Siegel* **1536**

Observed Bunched Electron Current in a Velocity-Modulated Beam, *Haruo Maeda* **1536**

Design of Transistor Regulated Power Supplies, *T. F. Kopaczek* **1537**

Use of Microwave Ferrite Toroids to Eliminate External Magnets and Reduce Switching Power, *M. A. Treuhaft and L. M. Silber* **1538**

A Theorem for Dissipationless Networks, *G. Szentirmai* **1538**

Cutoff Voltage Characteristics of TV Picture Tubes, *W. F. Niklas* **1539**

A Study of Earth Currents Near a VLF Monopole Antenna with a Radial Wire Ground System, *James R. Wait* **1539**

Design of Video Amplifiers with Stringent Electrical and Mechanical Requirements, *J. A. Develet, Jr.* **1541**

Networks of Fixed and Variable Resistors, *H. L. Armstrong* **1541**

Space-Charge Grid High-Transconductance Guns, *Paul H. Gleichauf* **1542**

REVIEWS

Scanning the TRANSACTIONS **1545**

Books:

- "Physique Electronique des Gaz et des Solides," by Michel Bayet, *Reviewed by J. I. Pankove* **1546**
- "The Exploration of Space by Radio," by R. H. Brown and A. C. B. Lovell, *Reviewed by F. T. Haddock* **1546**
- "Principles of Electrical Measurements," by H. Buckingham and E. M. Price, *Reviewed by G. B. Hoadley* **1547**

published monthly by The Institute of Radio Engineers, Inc.

Proceedings of the IRE®

continued

"An Introduction to the Theory of Random Signals and Noise," by W. B. Davenport, Jr., and W. L. Root, *Reviewed by W. M. Siebert* **1547**

"Atmospheric Explorations," ed. by H. G. Houghton, *Reviewed by A. W. Straiton* **1547**

"Soviet Education for Science and Technology," by A. G. Korol, *Reviewed by Ernst Weber* **1548**

"An Introduction to Digital Computers," by R. K. Livesley, *Reviewed by W. B. Cagle* **1548**

"Principles of Electronic Instruments," by G. R. Partridge, *Reviewed by Walther Richter* .. **1549**

"Zone Melting," by W. G. Pfann, *Reviewed by D. A. Jenny* **1549**

"Feedback Control Systems," by O. J. M. Smith, *Reviewed by G. S. Axelby* **1549**

"Electronic Semiconductors," by Eberhard Spenke, translated by D. Jenny, H. Kroemer, E. G. Ramberg, and A. H. Sommer, *Reviewed by G. C. Dacey* **1550**

"Photosensitors," by W. Summer, *Reviewed by Frederick Koury* **1550**

"Control Engineer's Handbook," ed. by J. G. Truxal, *Reviewed by J. M. Salzer* **1551**

"Van Nostrand's Scientific Encyclopedia," 3rd ed., *Reviewed by Gustave Shapiro* **1551**

Recent Books **1552**

ABSTRACTS

Abstracts of IRE TRANSACTIONS **1552**

Abstracts and References **1556**

IRE NEWS AND NOTES

Calendar of Coming Events and Authors' Deadlines **14A**

Call for Papers for the 1959 IRE National Convention **14A**

Professional Group News **16A**

Obituaries **16A**

National Symposium on Telemetering **16A**

DEPARTMENTS

Contributors **1543**

COVER Borrowing a leaf from the microwave field, a long range directional antenna has been developed for the 7 to 24 mc range in the form of a giant tapered aperture horn 850 feet long, 500 feet wide and 250 feet high by the U.S. Army Signal Communication Engineering Agency under contract with Developmental Engineering Corp., Washington, D.C., as reported in the article on page 1510.

BOARD OF DIRECTORS, 1958
*D. G. Fink, *President*
C. E. Granqvist, *Vice-President*
*W. R. G. Baker, *Treasurer*
*Haraden Pratt, *Secretary*
*J. D. Ryder, *Editor*
A. V. Loughren,
Senior Past-President
*J. T. Henderson,
Junior Past President

1958
A. N. Goldsmith
H. R. Hegbar (R4)
E. W. Herold
K. V. Newton (R6)
A. B. Oxley (R8)
F. A. Polkinghorn (R2)
D. B. Sinclair
*Ernst Weber
J. R. Whinnery

1958–1959
R. I. Cole (R3)
G. A. Fowler (R7)
*R. L. McFarlan (R1)
D. E. Noble
E. H. Schulz (R5)
Samuel Seely

1958–1960
G. S. Brown
W. H. Doherty

**Members of Executive Committee*

EXECUTIVE SECRETARY
George W. Bailey

Evelyn Benson, *Assistant to the Executive Secretary*

John B. Buckley, *Chief Accountant*

Laurence G. Cumming, *Technical Secretary*

Emily Sirjane, *Office Manager*

ADVERTISING DEPARTMENT
William C. Copp, *Advertising Manager*

Lillian Petranek, *Assistant Advertising Manager*

EDITORIAL DEPARTMENT
Alfred N. Goldsmith, *Editor Emeritus*
J. D. Ryder, *Editor*
E. K. Gannett, *Managing Editor*
Helene Frischauer, *Associate Editor*

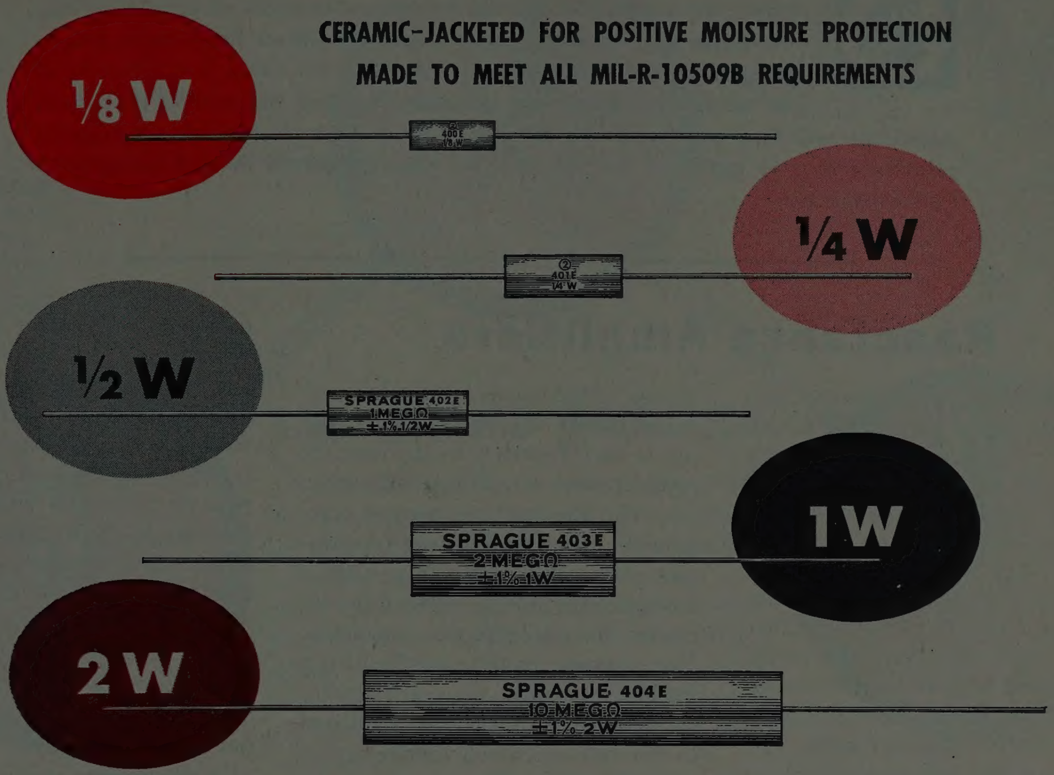
EDITORIAL BOARD
J. D. Ryder *Chairman*
F. Hamburger, Jr., *Vice-Chairman*
E. K. Gannett
Keith Henney
E. W. Herold
T. A. Hunter
G. K. Teal
W. N. Tuttle

PROCEEDINGS OF THE IRE, published monthly by The Institute of Radio Engineers, Inc., at 1 East 79 Street, New York 21, N. Y. Manuscripts should be submitted in triplicate to the Editorial Department. Responsibility for contents of papers published rests upon the authors, and not the IRE or its members. All republication rights, including translations, are reserved by the IRE and granted only on request. Abstracting is permitted with mention of source.

Fifteen days advance notice is required for change of address. Price per copy: members of the Institute of Radio Engineers, one additional copy $1.25; non-members $2.25. Yearly subscription price: to members $9.00, one additional subscription $13.50; to non-members in United States, Canada, and U. S. Possessions $18.00; to non-members in foreign countries $19.00. Entered as second class matter, October 26, 1927, at the post office at Menasha, Wisconsin, under the act of March 3, 1879. Acceptance for mailing at a special rate of postage is provided for in the act of February 28, 1925, embodied in Paragraph 4, Section 412, P. L. and R., authorized October 26, 1927. Printed in U.S.A. *Copyright © 1958 by The Institute of Radio Engineers, Inc.*

Airborne Instruments Laboratory Monograph on page 4A.

CERAMIC-JACKETED FOR POSITIVE MOISTURE PROTECTION
MADE TO MEET ALL MIL-R-10509B REQUIREMENTS


1/8 W
②
400E
1/8 W
1/4 W
②
401E
1/4 W
1/2 W
SPRAGUE 402E
1MEGΩ
±1% 1/2W
1W
SPRAGUE 403E
2MEGΩ
±1% 1W
2W
SPRAGUE 404E
10MEGΩ
±1% 2W

FILMISTOR☆

CARBON FILM RESISTORS IN RATINGS FROM 1/8 TO 2 WATTS PROVIDE THE STABILITY YOU WANT UNDER THE TOUGHEST LOAD AND HUMIDITY CONDITIONS

WRITE FOR BULLETIN NO. 7010A • SPRAGUE ELECTRIC COMPANY
235 MARSHALL STREET • NORTH ADAMS, MASSACHUSETTS

☆ TRADEMARK REG.

SPRAGUE®
THE MARK OF RELIABILITY

SPRAGUE COMPONENTS: RESISTORS • CAPACITORS • MAGNETIC COMPONENTS • TRANSISTORS
INTERFERENCE FILTERS • PULSE NETWORKS • HIGH TEMPERATURE MAGNET WIRE • PRINTED CIRCUITS

Reactance amplifiers are currently a subject of much interest, primarily because—like Masers—they are capable of providing very low-noise amplification. At AIL such amplifiers have been undergoing intensive study and development for some time. Results of our work have been very encouraging, and we believe that these amplifiers will find application in the near future. Because the subject may be relatively new to many of our readers, we have prepared the following brief "advertisement."

Reactance Amplifiers

Reactance amplifiers — also sometimes called parametric amplifiers—are modern high frequency versions of the older dielectric and magnetic amplifiers. The basic element of such amplifiers is an energy storage device whose reactance can be varied periodically. The device may take a variety of forms, either tube or solid-state, but to be useful for low-noise amplification it must be relatively lossless and also essentially free of other sources of noise. For example, it may be a nearly ideal capacitor whose charge versus voltage characteristic is nonlinear. A characteristic of this type, useful up to extremely high frequencies, is provided by a properly made reverse-biased p-n junction diode. The instantaneous charge can be varied periodically by connecting a local oscillator, or "pump," to the device. This driving source constitutes an ac power supply; it performs the same function as the dc power supply in a conventional amplifier. Because the device characteristic is nonlinear, the resultant charge, and therefore also its derivative—the current—is a distorted version of the wave shape of the driving voltage. If an ac signal voltage is also applied, the current is multiperiodic; it contains components of signal frequency, pump frequency, and the sum and difference of these frequencies, among others. In this respect, operation is similar to the conventional nonlinear resistance mixer. An important difference, however, is that because the latter is not an energy storage device, amplification is not possible. In contrast, in the reactance amplifier, the nonlinear reactor is the means by which power is abstracted from the ac power supply at one frequency to augment the signal power at another frequency.

The existence of current components of many different frequencies makes it possible to operate a reactance amplifier in many different modes, having different properties. For example, in the sum-frequency mode of operation, the sum-frequency component of current is utilized to develop an output voltage across a resonant load. The output voltage is subsequently demodulated to recover the signal envelope. In our initial work, an amplifier of this type was constructed and tested to seek experimental verification of its theoretical properties. To facilitate the work, commercially available junction diodes were utilized, with relatively low signal and pump frequencies. Experimental results were very good indeed, theory being verified in all important particulars, including those of appreciable gain, large bandwidth, and very low noise.* This work has since been extended to signal frequencies of the order of 500 Mc, again with excellent results.

Another form of operation, the properties of which resemble in many ways those of a three-level Maser, is obtained with the difference-frequency mode. In this type of reactance amplifier the load is coupled to the signal circuit, either directly or through a circulator. An auxiliary circuit, resonant to the difference-frequency component of current, is utilized to provide a difference-frequency voltage; this circuit is an "idler," from which no power is abstracted. As in the Maser, the conductance presented to the signal circuit is negative, with the result that the signal voltage is amplified, but at the expense of a narrowed bandwidth. A variant of this mode of operation is obtained by coupling the load to the difference-frequency circuit, rather than to the signal circuit; in this case the amplified signal envelope is recovered by subsequent demodulation.

Many other modes of operation are possible. For further information the interested reader is referred to the June 1958 issue of Proc. IRE, which contains several informative articles by workers from other laboratories, as well as the brief account of our own initial work.

---

* B. Salzberg and E. W. Sard, *A Low-Noise Wide-Band Reactance Amplifier*, Proc. IRE, vol. 46, p. 1303; 1958.

A complete bound set of our second series of articles is available on request. Write to Harold Hechtman at AIL for your set.

Airborne Instruments Laboratory

A DIVISION OF CUTLER-HAMMER, INC.
160 OLD COUNTRY ROAD, MINEOLA, L. I., N. Y.
Phone Pioneer 2-0600

surface barrier transistors from **SPRAGUE***

actual size

2N128
General Purpose
(MIL-T-12679A)

	Min.	Typ.	Max.
hfe	19	32	66
fmax	45	65	—

2N344/SB101
for Medium Gain
Amplifiers

	Min.	Typ.	Max.
hfe	11	23	83
fmax	30	45	—

2N345/SB102
for High Gain
Amplifiers

	Min.	Typ.	Max.
hfe	25	40	110
fmax	30	45	—

now in mass production

Surface Barrier Transistors are now available from Sprague in production quantities for general high frequency applications and for high speed computer switching circuits. Orders for the popular types shown here are shipped promptly. They're priced right . . . and their high quality and excellent electrical characteristics make them the ideal solution to many difficult circuit requirements.

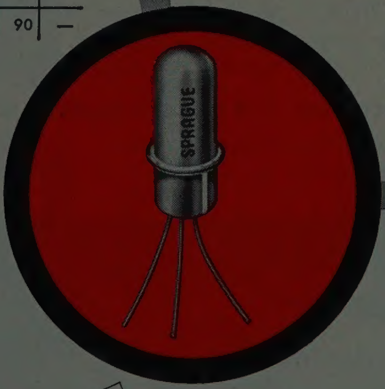
* Sprague surface barrier transistors are fully licensed under Philco patents. All Sprague and Philco transistors having the same type number are manufactured to the same specifications and are fully interchangeable. You have two sources of supply when you use surface barrier transistors!

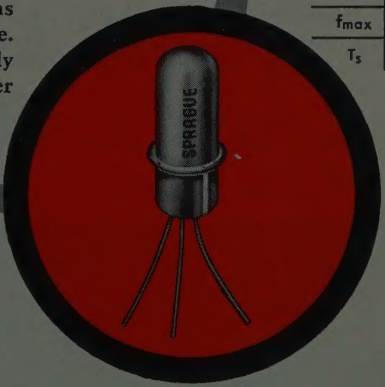
2N346/SB103
for High Frequency
Oscillators

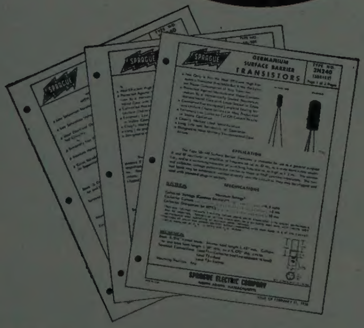
	Min.	Typ.	Max.
hfe	10	—	—
fmax	60	90	—

2N240/SB5122
for Computer
Switching

	Min.	Max.
hfe	16	—
fmax	30	—
T_s	—	80



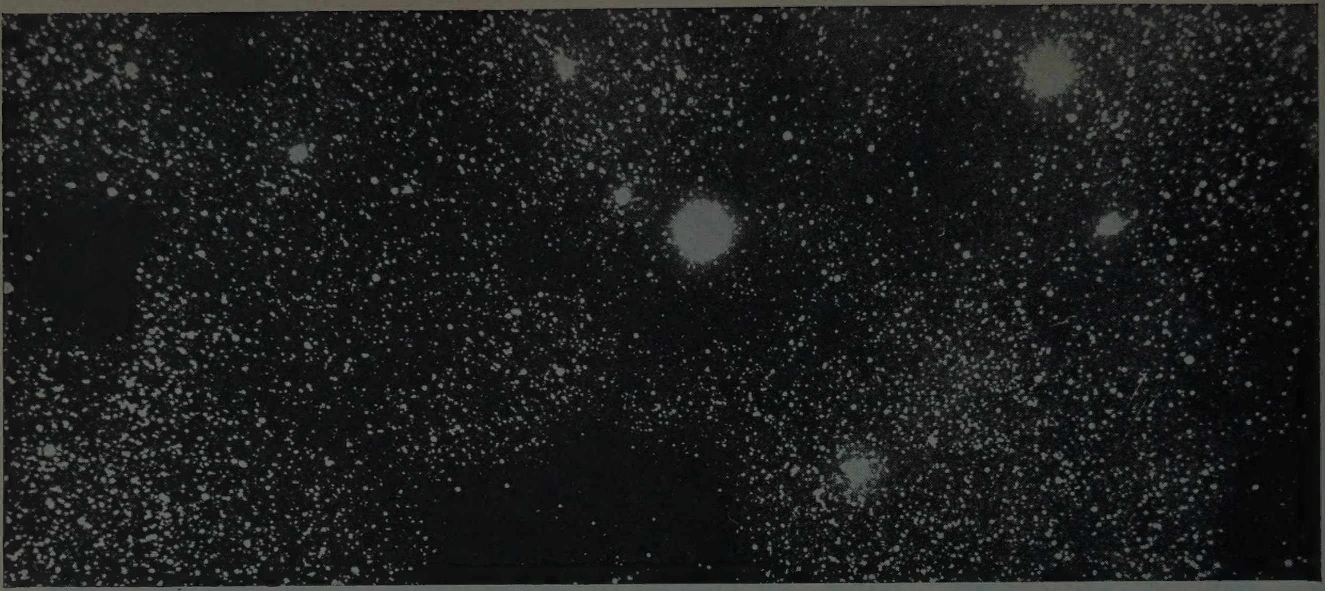




WRITE FOR COMPLETE ENGINEERING DATA SHEETS ON THE TYPES IN WHICH YOU ARE INTERESTED. ADDRESS REQUEST TO THE TECHNICAL LITERATURE SECTION, SPRAGUE ELECTRIC CO., 23 MARSHALL ST., NORTH ADAMS, MASS.

SPRAGUE®
the mark of reliability

TRANSISTORS • RESISTORS • MAGNETIC COMPONENTS
CAPACITORS • INTERFERENCE FILTERS • PULSE NETWORKS
HIGH TEMPERATURE MAGNET WIRE • PRINTED CIRCUITS



Courtesy Mount Wilson Observatory

FROM BEYOND THE SKY
TO BENEATH THE SEAS

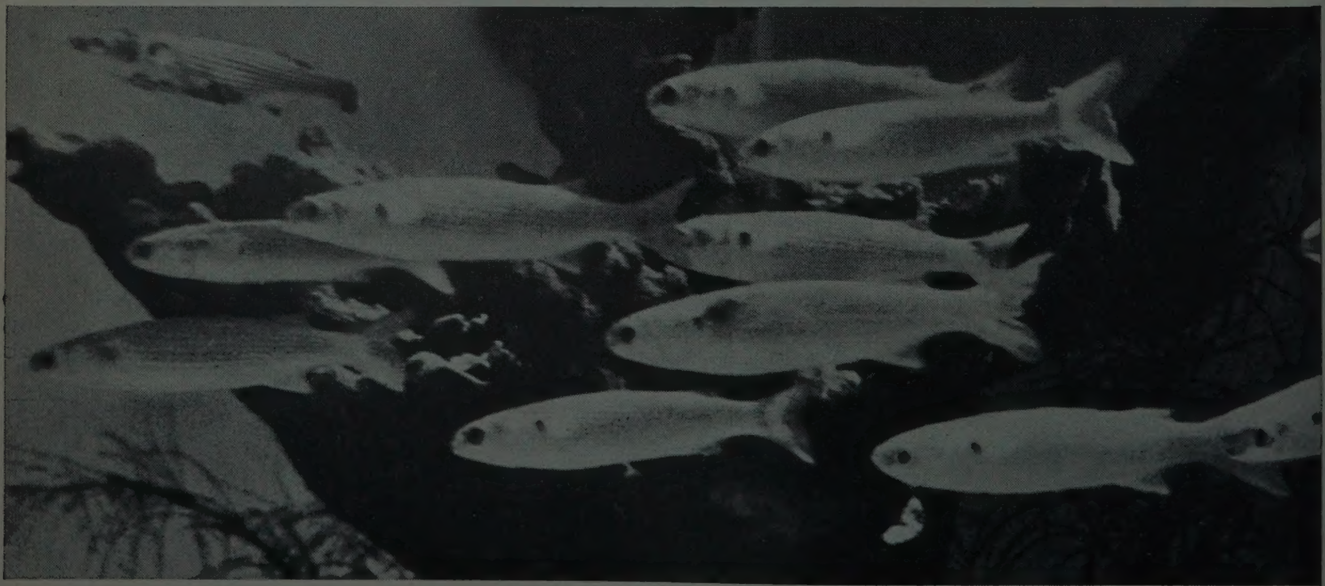
In the field of communications, two extraordinary events have occurred within a short span of time. One was the linking of Europe to America by the submarine telephone cable. The other was the sending of radio signals from U. S. satellites in outer space.

Both achievements depended on developments from Bell Telephone Laboratories. The cable was made possible by development of long-life electron tube amplifiers able to withstand crushing pressure on the ocean floor. The satellites derive their radio voices from transistors—products of basic research in semiconductor physics.

The deep sea amplifier and the transistor illustrate the wide range of work at Bell Telephone Laboratories. Here, over 3000 professional scientists and engineers explore and develop in physics, mathematics, electronics, chemistry, mechanical engineering, even biology—in every art and science which can help improve electrical communications.

Through this work, Bell Telephone Laboratories has helped make your telephone service the world's finest—and will keep it so.

BELL TELEPHONE LABORATORIES
WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT



JUST
ANNOUNCED!

-hp- voltmeters for every need

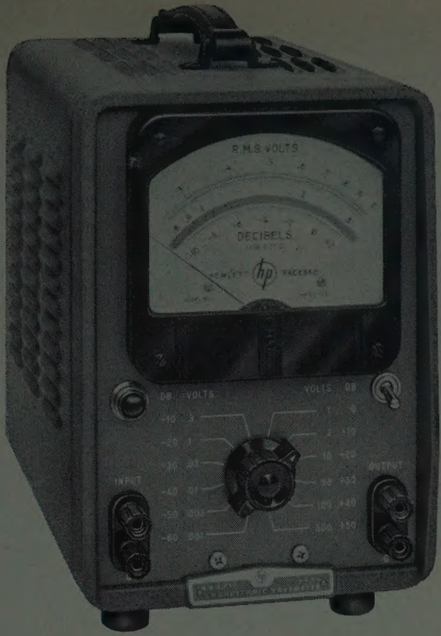
-hp- 410B — 20 cps to 700 MC, ac or dc coverage, also dc VTVM with over 100 megohms input impedance, or ohmmeter 0.2 ohms to 500 megohms. Ac measurement input capacity 1.5 $\mu\mu$f, input impedance 10 megohms. Standard voltmeter of electronics industry. $245.00.

-hp- 400H — 1% accuracy to 500 KC, ±2% to 1 MC, ±5% full range. 10 cps to 4 MC; 5″ mirror scale meter, range 0.1 mv to 300 v. 10 megohm input impedance minimizes loading. 56 db amplifier feedback insures highest stability. $325.00.

-hp- 400AB—high value multipurpose VTVM. 10 cps to 600 KC, range 0.3 mv to 300 v, 11 ranges. High stability, sensitive, accuracy ±2% to 100 KC. 10 megohm input impedance. Reads direct in volts, dbm. $200.00.

-hp- 400D, best VTVM value built. 10 cps to 4 MC, accurate within ±2% to 1 MC, range 0.1 mv to 300 v. Reads direct in v, dbm. High 10 megohm input impedance prevents circuit loading. New 56 db feedback amplifier circuit insures highest stability. $225.00.

Data subject to change without notice. Prices f.o.b. factory.



-hp- 400L LOGARITHMIC VOLTMETER

High accuracy
5″ true log voltage scale
10 cps to 4 MC
12 db linear scale
10 db range steps
Generous scale overlap

New Model 400L's logarithmic voltage scale plus long scale length provides an instrument of maximum readability and an accuracy which is a *constant percentage of the reading.* Voltage scales are more than 5″ long, with a 12 db scale spread across the full scale length. The meter is mirror backed for maximum accuracy. A range switch changes voltage sensitivity in 10 db intervals. This feature, together with the 12 db scale, provides generous overlap and is of particular convenience in work involving decibel levels. Accuracy is ±2% of reading or ±1% of full scale, whichever is more accurate, to 500 KC.

Features of the new 400L include 0.3 mv to 300 v range (12 steps, 1-3-10-30 sequence), high stability, 10 megohm input impedance, large overload capacity, compact size. The instrument is also a stable amplifier. Model 400L (cabinet) $325.00; (rack mount) $330.00.

HEWLETT-PACKARD COMPANY
4816D PAGE MILL ROAD • PALO ALTO, CALIFORNIA, U.S.A.
CABLE "HEWPACK" • DAVENPORT 5-4451
FIELD ENGINEERS IN ALL PRINCIPAL AREAS

4816

hp value standard of the industry

See These Products At The 1958 Wescon Convention Booths #1640, 1641

Available From Stock!
Additional New Features!
Moderately Priced!

ERA's TRANSISTORIZED HIGH CURRENT REGULATED POWER SUPPLIES

Ratings up to 12 Amps!

IDEAL FOR:

- *Battery Substitution*
- *Computers*
- *Transistor Bias*
- *Motor and Relay Control*
- *Television*
- *All High Current Laboratory and Industrial Applications*

SPECIFICATIONS

Models listed are designed for 105-125 VAC input, 60-400 cps. Continuously adjustable output. Line regulation is within ±0.5%. Load regulation is within ±0.5%. Front panel regulation control. Frequency response of regulator extends into high audio frequencies. Ripple less than 0.05% or 5 mv. Current limiter control on front panel for full overload and circuit protection. Units are for bench or standard 19" rack mounting.

FEATURES

- *Continuously Variable Output*
- *Vernier Voltage Control*
- *Fast Transient Response*
- *Low Output Ripple*
- *Positive, Negative, Zero % Regulation Control*
- *Line Frequency Insensitive*
- *Remote Sensing*
- *Constant Current Overload Limit Control*
- *Positive or Negative Outputs, Ungrounded*
- *Terminals On Front and Rear*
- *Hinged Panel For Full Accessibility*
- *High Efficiency*
- *Low Heat Dissipation*
- *Compact, Light Weight*
- *Instant Warm-up Time*

TYPICAL STOCK MODELS

Model Number	Voltage VDC	Current Amps.	Output DC R (ohms)	Price FOB Factory
TR32-4	4-32	0-4	0.01	$455.00
TR32-8	4-32	0-8	0.005	$495.00
TR32-12	4-32	0-12	0.002	$575.00
TR150-1	20-150	0-1	0.5	$455.00

Additional stock models also available.

Special designs also made to customers specifications. Write for quotation.

Pioneers in Semi-Conductor and Transistorized Products.

First Miniaturized Power Packs.
First Transistorized Power Supplies.
First Automatic Transistor Test Equipment.
First Dual Output Tubeless Supplies.
First Packaged Transistor Circuits.
First Transistor Application Power Supplies.
First Constant Current Generators.
First High Current Semi-Conductor Regulated Supplies.
First "E" Core Transistorized Converters/Inverters.
First High Power Semi-Conductor Frequency Changers.

ELECTRONIC RESEARCH ASSOCIATES
67 Factory Place, Cedar Grove, N. J.
CEnter 3-9000
SUBSIDIARIES
ERA PACIFIC INCORPORATED • SANTA MONICA, CALIFORNIA
ERA ELECTRIC CORPORATION • NUTLEY, NEW JERSEY

Meetings with Exhibits

As a service both to Members and the industry, we will endeavor to record in this column each month those meetings of IRE, its sections and professional groups which include exhibits.

Δ

August 6-8, 1958

Special Technical Conference on Non-Linear Magnetics and Magnetic Amplifiers, Hotel Statler, Los Angeles, Calif.

Exhibits: Mr. Philip Diamond, Perkin Engineering Corp., 345 Kansas St., El Segundo, Calif.

August 19-22, 1958

Western Electronic Show and Convention, Ambassador Hotel and Pan Pacific Auditorium, Los Angeles, Calif.

Exhibits: Mr. Don Larson, WESCON, 1435 La Cienega Blvd., Los Angeles, Calif.

September 12-13, 1958

Conference on Communications, Sheraton-Montrose Hotel, Cedar Rapids, Iowa

Exhibits: Mr. Don Loop, Box 948, Cedar Rapids Iowa

September 22-24, 1958

National Symposium on Telemetering, Americana Hotel, Miami Beach, Fla.

Exhibits: Mr. L. P. Clark, Tele-Dynamics, Inc., 5000 Parkside Ave., Philadelphia 31, Pa.

October 8-10, 1958

IRE Canadian Convention, Exhibition Park, Toronto, Canada.

Exhibits: Mr. Grant Smedmor, IRE Canadian Convention, 1819 Yonge St., Toronto, Canada.

October 13-15, 1958

National Electronics Conference, Hotel Sherman, Chicago, Ill.

Exhibits: Mr. Brendan C. Hawkins, National Electronics Conference, Inc., 84 E. Randolph St., Chicago 1, Ill.

October 20-22, 1958

Fourth Annual Symposium on Aeronautical Communications, Hotel Utica, Utica, N.Y.

Exhibits: Mr. Robert E. Gaffney, 50 Cambridge Rd., Whitesboro, N.Y.

October 27-29, 1958

East Coast Aeronautical and Navigational Electronics Conference, Lord Baltimore Hotel & 7th Regiment Armory, Baltimore, Md.

Exhibits: Mr. R. L. Pigeon, Westinghouse Electric Corp., Air Arm Div., P.O. Box 746, Baltimore, Md.

November 19-20, 1958

Northeast Electronics Research and Engineering Meeting (NEREM), Mechanics Building, Boston, Mass.

Exhibits: Mr. Stuart K. Gibson, Instruments of New England, 108 Greenwood Lane, Waltham 54, Mass.

(Continued on page 10A)

Truly Flexible High Frequency Attenuators at 50, 70, or 90 Ohm Impedances

NEW and IMPROVED!

KAY
Attenuators

Improved Kay Attenuators are now available in 12 models offering a choice of 50 ohm, 70 ohm, or 90 ohm impedance . . . attenuation in 1 db steps as high as 119 db . . . a choice of a fixed 10 db insertion loss or zero insertion loss with almost negligible error . . . new compact housings of lightweight cast aluminum . . . and *greater accuracy than ever!*

- **Fast Switching to Check Points (½ Power, etc.) at Any Pre-Set Reference Level**
- **0-119 db in 1 db Steps from Single Unit**
- **Ruggedized High Frequency Switches—Solid Silver Contacts in Teflon—for Low Loss and Superior Match**
- **1% Carbon Film Resistors for Highest Accuracy and Stability**
- **Essentially Flat Frequency Response**

SPECIFICATIONS

	MODEL CAT. NO. 20* 430-B 21† 440-B 22‡ 450-B	MODEL CAT. NO. 20-0* 431-B 21-0† 441-B 22-0‡ 451-B	MODEL CAT. NO. 30-0* 432-C 31-0† 442-C 32-0‡ 452-C	MODEL CAT. NO. 40-0* 433-A 41-0† 443-A 42-0‡ 453-A
Z_{in} Z_{out}	*50 ohms nom.	†70 ohms nom.		‡90 ohms nom.
DB Switched	41 db in 6 steps		101 db in 9 steps	119 db total in 1-db steps
Steps	20 db, 10 db, 5 db, 3 db, 2 db, 1 db		Same as 41-db units, plus 3 extra 20-db steps	1 db and 10 db
INSERTION LOSS	10 db	Zero db at low frequencies; approx. 0.1 db at 250 mc; approx. 0.2 db at 500 mc		
Maximum Total Error (includes insertion loss)	At full attenuation: 0.5 db at 250 mc; 1.2 db from 250 to 500 mc		At full attenuation: 1.0 db at 250 mc; 2.0 db from 250 to 500 mc	
	BETTER ACCURACY AT LOWER FREQUENCIES AND/OR USING FEWER ATTENUATION STEPS			
Frequency Range	DC to 500 mc; useful to 1000 mc			
SWR	1.2:1 max. up to 250 mc; 1.4:1 max., 250 to 500 mc			
Maximum Power	½ watt			
Connectors	BNC type UG-185/U			
Dimensions	2" x 7" x 2"		2" x 9¾" x 2"	5¾" x 5¾" x 3½"
Weight	2 lbs.		3 lbs.	4¼ lbs.
Prices	$65.00	$60.00	$95.00	$195.00

All prices f.o.b. factory.

NOTE: Kay *Attenuators* can be made on special order in 0.5 db steps and to customer's choice of insertion loss, attenuation range, and impedance rating.

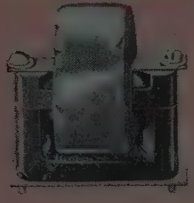
SEE US AT THE WESCON SHOW: Booth 643

Write for 1958 Kay Catalog

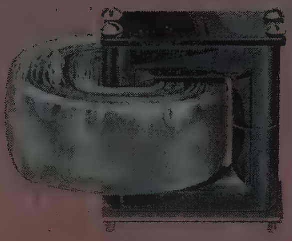
KAY ELECTRIC COMPANY

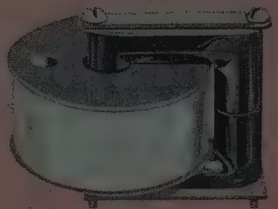
Dept. I-8 MAPLE AVENUE PINE BROOK, N.J. CApital 6-4000

TRANSFORMER NEWS FROM TRIAD


TY-68S

TY-74S


TY-70S TY-71S


TY-69S

Type No.	*D.C. Volts Output	D.C. Ma.	Max. Watts	Net Price
TY-68S	250	65	16¼	$8.34
TY-69S	300	100	30	10.56
TY-70S	325	150	48¾	11.40
TY-71S	375	200	75	12.30
TY-74S	600	200	120	15.00

*Center tap output winding provides half voltage at full rated current, high side full voltage at half current.

NEW POWER TRANSFORMERS

FOR 12-VOLT TRANSISTOR POWER SUPPLIES

Center tapped output windings permit two simultaneous voltages to be used, providing the total power in output watts is not exceeded. These new transformers are especially designed for mobile transistorized power supplies. Power supplies using these transformers have an efficiency of 80 to 85%.

IMMEDIATE DELIVERY! They are available now from your nearby Triad Distributor. Ask him for special bulletin giving schematic and specifications or write direct to Triad for this information.

RIQAP

(Reduced Inspection—Quality Assurance Plan) Your own incoming inspection and field service requirements are reduced to a minimum when you specify Triad. All Triad Transformers are manufactured under this Signal Corps approved plan for quality assurance. RIQAP is awarded only to those companies who continue to maintain Signal Corps standards.

TRIAD

TRIAD TRANSFORMER CORPORATION

4055 REDWOOD AVENUE
VENICE, CALIFORNIA

812 EAST STATE STREET
HUNTINGTON, INDIANA

A SUBSIDIARY OF LITTON INDUSTRIES

Meetings with Exhibits

(Continued from page 8A)

December 3-5, 1958

Eastern Joint Computer Conference, Bellevue Stratford Hotel, Philadelphia, Pa.

Exhibits: Mr. L. D. Whitelock, BuShips, Room 1025, Main Navy Building, Washington 25, D.C.

December 3-5, 1958

Second National Symposium on Global Communications, St. Petersburg, Fla.

Exhibits: Mr. Robert L. Lazarchik, Sperry-Rand Corp., P.O. Box 1828, Clearwater, Fla.

December 4-5, 1958

PGVC Annual Meeting, Hotel Sherman, Chicago, Ill.

Exhibits: Mr. Frederick L. Hilton, 4501 Augusta Blvd., Chicago, Ill.

December 9-11, 1958

Mid-America Electronics Convention, Municipal Auditorium, Kansas City, Mo.

Exhibits: Mr. Leo Schlesselman, Bendix Aviation Corp., Box 1159, Kansas City 41, Mo.

February 2-4, 1959

Seventh Regional Conference and Trade Show, University of New Mexico, Albuquerque, N.M.

Exhibits: Mr. Ewald W. Berger, 3421 58th St., Sacramento 20, Calif.

March 2-6, 1959

Western Joint Computer Conference, Fairmont Hotel, San Francisco, Calif.

Exhibits: Mr. David F. Weinberg, Ramo-Wooldridge Corp., P.O. Box 45067, Airport Station, Los Angeles, Calif.

March 23-26, 1959

Radio Engineering Show and National IRE Convention, New York Coliseum and Waldorf-Astoria Hotel, New York, N.Y.

Exhibits: Mr. William C. Copp, Institute of Radio Engineers, 72 West 45th St., New York 36, N.Y.

April 16-18, 1959

South Western IRE Regional Conference & Electronics Show, Dallas, Tex.

Exhibits: Mr. Durward Tucker, WRR, State Fair Grounds, Dallas, Tex.

May 11-13, 1959

National Aeronautical and Navigational Electronics Conference, Dayton Biltmore Hotel, Dayton, Ohio.

Exhibits: Mr. John Kinnally, 203 Talbott Bldg., Dayton 2, Ohio.

△

Note on Professional Group Meetings: Some of the Professional Groups conduct meetings at which there are exhibits. Working committeemen on these groups are asked to send advance data to this column for publicity information. You may address these notices to the Advertising Department and of course listings are free to IRE Professional Groups.

NEED RELIABLE POWER?

MODEL MTR 636-15
6-36 VOLTS @ 15 AMPS

OTHER RATINGS AVAILABLE

MODEL NUMBER	D.C. OUTPUT RATING
MTR28-10	24-32 Volts @ 10 Amps
MTR28-30	24-32 Volts @ 30 Amps
MTR28-100	24-32 Volts @ 100 Amps
MTR060-1	0-60 Volts @ 1 Amp
MTR060-5	0-60 Volts @ 5 Amps
MTR636-30	6-36 Volts @ 30 Amps

NOW:

PERKIN TRANSIENT FREE DC POWER SUPPLIES WITH PROVEN RELIABILITY - - -

feature the rugged dependability of magnetic amplifiers combined with the precise regulation of transistors in a unique power supply circuit eliminating load-damaging overshoots.

For further information contact your local representative listed below or wire factory collect.

PERKIN

ENGINEERING CORPORATION

345 KANSAS ST., EL SEGUNDO, CALIF.
ORegon 8-7215, EAstgate 2-1375

NEW YORK AREA OFFICE HUnter 2-8608	SAN FRANCISCO, CALIF. EMerson 9-3354	SYRACUSE, N.Y. GIbson 6-0220	SAN DIEGO, CALIF. ACademy 2-7516	ALBUQUERQUE, NEW MEXICO 8-1724	LOS ANGELES, CALIF. HO 9-7294
CHICAGO, ILLINOIS PAlisade 5-6824	CLEVELAND, OHIO REdwood 2-7444	PHOENIX, ARIZONA AMherst 5-0274	ATLANTA, GEORGIA CEdar 7-7801	MINNEAPOLIS, MINNESOTA MIdway 6-2621	DENVER, COLORADO ALpine 5-1196
SEATTLE, WASHINGTON PArkway 3-9000	DETROIT, MICHIGAN HO 8-2461	ORLANDO, FLORIDA CH 1-2128	DAYTON, OHIO CHapel 4-5551	NEW ENGLAND AREA OFFICE MUrdock 3-3252	CANADA AXminster 3-7011

1958

NATIONAL SYMPOSIUM ON TELEMETERING

Americana Hotel

September 22-24

MIAMI BEACH, FLORIDA

PLAN TO ATTEND

Registration:

Mr. W. H. Eppeson
Aeronautical Equipment Co.
3090 Douglas Road
Miami, Florida

Monday, Sept. 22

Session I (five papers)
DIGITAL TECHNIQUES

Session II (six papers)
TRANSISTOR TELEMETRY COMPONENTS

Session III (six papers)
TELEMETRY IN SPACE

Session IV (six papers)
NEW COMPONENTS IN TELEMETRY

Tuesday, Sept. 23

Session V (six papers)
DATA RECORDING AND PROCESSING

Session VI (five papers)
NEW RADIO FREQUENCY TECHNIQUES AND PROBLEMS

Session VII (five papers)
DYNAMIC TESTING IN THE SPACE AGE

Session VIII (five papers)
MODULATION—METHODS IN TELEMETRY

Wednesday, Sept. 24

Session IX (five papers)
THE INSTRUMENTATION OF OUTER SPACE

Session X (six papers)
RECENT TECHNICAL ADVANCES IN COMMUTATORS

Session XI (five papers)
NEW TELEMETRY SYSTEMS

Session XII (five papers)
TIME DIVISION MULTIPLEXING SYSTEMS

PLAN TO EXHIBIT

1958 exhibitors to date:

Airpax Products Company
Ampex Corporation
Arnoux Corporation
Bendix Aviation Corporation
Computer Control Company, Inc.
Consolidated Electrodynamics, Inc.
Cubic Corporation
Data-Control Systems, Inc.
Dynamic Gear Company, Inc.
Electro-Mechanical Research

Exhibits Manager:

Mr. L. P. Clark
5000 Parkside Avenue
Philadelphia 31, Pa.

Epsco, Inc.
Fenske, Fedrick & Miller
General Devices, Inc.
General Electronic Labs., Inc.
Instrument Development Labs., Inc.

Arthur H. Lynch & Assoc.
Magnetic Research Corp.
Murphy & Cota
Mycalex Electronics Corp.
Nems-Clarke Co.
J. M. Ney Co.
Panoramic Radio Prods.
Radiation, Inc.
Telechrome Mfg. Corp.
Tele-Dynamics, Inc.
Telemeter Magnetics, Inc.
Trans-Sonics, Inc.

Sponsored by

THE PROFESSIONAL GROUP ON TELEMETRY & REMOTE CONTROL OF THE IRE

A NEW POWER FERRITE for FLYBACK TRANSFORMERS by ALLEN-BRADLEY

A-B QUALITY

HIGHER FLUX DENSITY
LOWER CORE LOSSES
HIGHER CURIE POINT

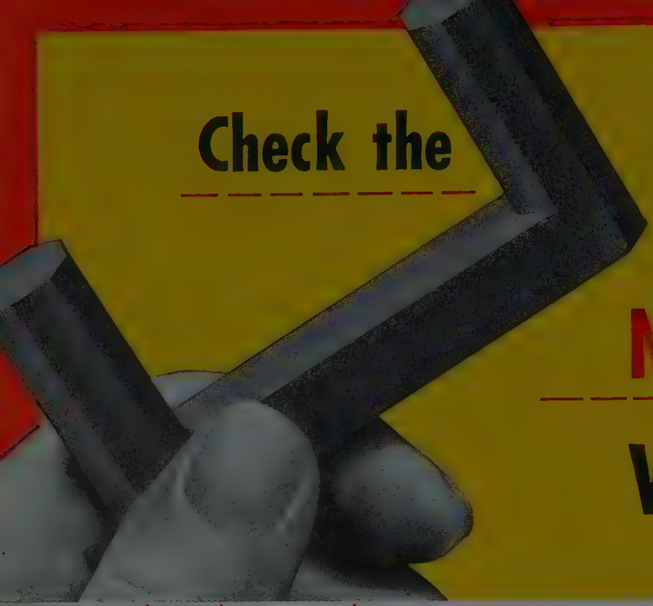
Now, with the higher flux density of Allen-Bradley's new Class W-04 ferrite, you can design smaller flyback transformers with smaller cores. This saves space . . . saves weight . . . and saves copper, too. And the new ferrite is priced so that, with this smaller size, the actual cost of the core itself is also reduced.

Specify Allen-Bradley's new W-04 ferrite for *your* flyback transformers. The table on the following page compares the superior characteristics of the new W-04 with Allen-Bradley's "premium quality" W-03 ferrite.

ALLEN-BRADLEY CO.
ELECTRONIC COMPONENTS

Allen-Bradley Co.
222 W. Greenfield Ave.
Milwaukee 4, Wisconsin

In Canada—
Allen-Bradley Canada Ltd.
Galt, Ontario



Check the superior characteristics of this NEW ALLEN-BRADLEY W-04 Power Ferrite

Class	Temp. °C	B_{max}* in Gauss at 10 Oe	Core Loss P_h in $\frac{\mu Watts}{cm3cps}$ B=1350 Gauss 16 Kcps	B=1350 Gauss 60 Kcps	B=1800 Gauss 16 Kcps	B=1800 Gauss 60 Kcps	μ_{max}*	μ_0 at Room Temp.	B_u**	μ at B_u †	Curie Temp. °C
RECOMMENDED FOR FLYBACK TRANSFORMER CORES (AND OTHER POWER APPLICATIONS)											
W-04	25	4900 ± 10%	3.8 ± 20%	5.3 ± 20%	6.4 ± 20%	9.0 ± 20%	7000 ± 30%	2000	2700 ± 15%	6000 ± 25%	225
	115	3700 ± 10%	3.8 ± 20%	5.3 ± 20%	6.4 ± 20%	9.0 ± 20%	7000 ± 30%				
W-03	25	4200 ± 10%	4.1 ± 20%	5.5 ± 20%	6.9 ± 20%	9.1 ± 20%	6000 ± 30%	2000	2100 ± 15%	5600 ± 25%	180
	115	2800 ± 10%	4.2 ± 20%	6.5 ± 20%	6.9 ± 20%	10.0 ± 20%	6000 ± 30%				
RECOMMENDED FOR TV YOKE CORES											
W-01	25	2850 ± 10%	5.8 ± 30%	9.5 ± 30%	9.2 ± 30%	16.0 ± 30%	5000 ± 20%	850	1200 ± 20%	5000 ± 25%	180
	115	2000 ± 10%	4.4 ± 30%	7.9 ± 30%	7.4 ± 30%	14.5 ± 30%	6000 ± 30%				

*B_{max} and μ_{max}, Frequency—16 Kcps.

**Usable flux density—flux density at which the 115°C permeability is equal to ½ of the 25°C permeability.

†Permeability of the core at 25°C at B_u.

The above table shows the superiority of the new W-04 ferrite—higher flux density, higher permeability, lower core loss . . . properties that permit significant improvement in your flyback transformer design.

Allen-Bradley has also developed new square-loop power ferrites (R-03), and ferrites with unique characteristics for transistorized medium frequency power inverters (W-07).

The experienced engineering staff at Allen-Bradley will be glad to assist you with your ferrite problems. Write, today!

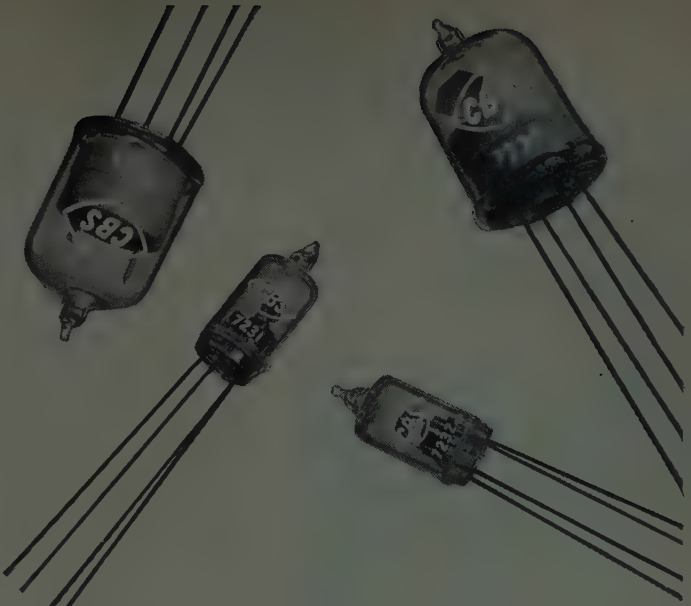
Allen-Bradley ferrites are available in a wide range of shapes and sizes for various applications. Just a few of the basic shapes and sizes are shown above.

Allen-Bradley Co.
222 W. Greenfield Ave., Milwaukee 4, Wis.
In Canada—
Allen-Bradley Canada Ltd., Galt, Ont.

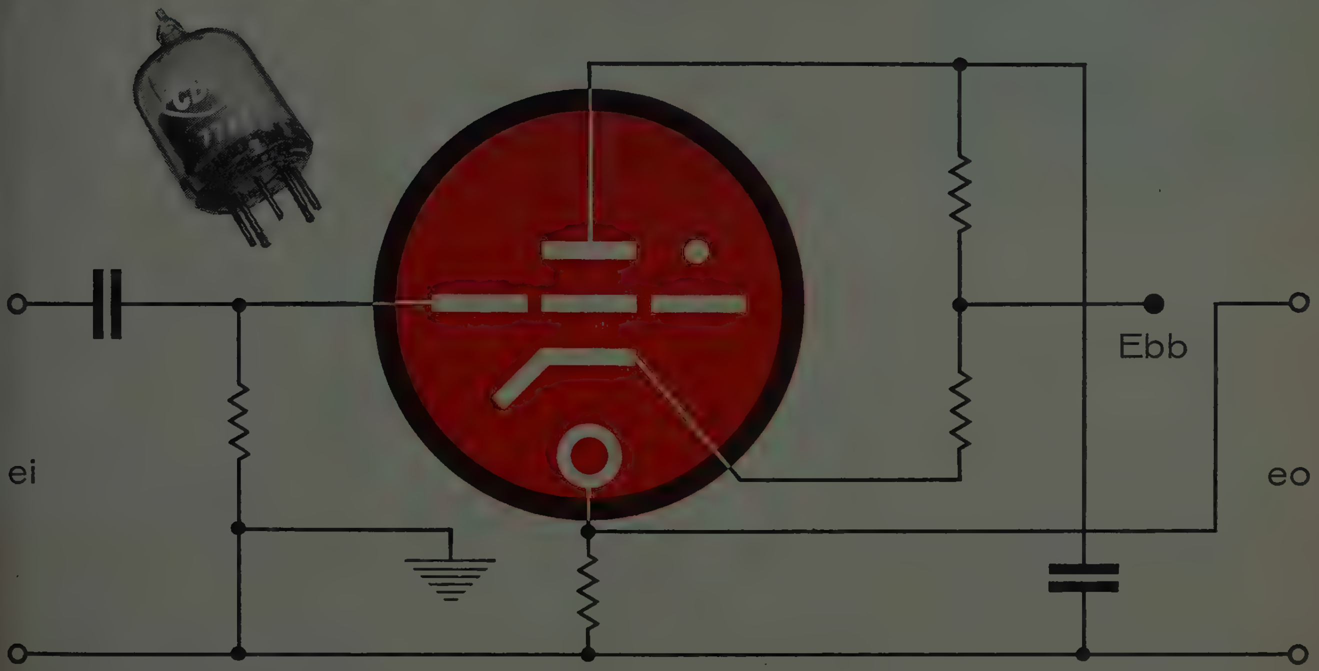
A-B QUALITY

ALLEN-BRADLEY CO.
ELECTRONIC COMPONENTS

The miniature 7205, 7229 and 7230 and subminiature 7231 and 7232 . . . CBS-Hytron originals . . . introduce a new and growing family of fast-switching krytrons. These cold-cathode trigger tubes are efficient and accurate. They replace relays and thyratrons in simpler circuits for reliable military and industrial equipment. They control up to 500 amperes with input signals of fewer than 20 microamperes. And they are designed to operate under extreme conditions of heat, shock and vibration. You will find these new krytrons useful as electronic relays . . . timers . . . oscillators . . . sensers . . . and pulsers. Check their features and characteristics. Write for CBS-Hytron Bulletin E-287.



KRYTRON... NEW ELECTRONIC SWITCH



FEATURES

1. Rugged and reliable
2. Compact and light
3. Silent and cool
4. Stable inert gas fill
5. Instant-firing keep-alive
6. Sure dark/cold starts
7. Negligible jitter

MAJOR CHARACTERISTICS

• High hold-off voltages	1000, 2000, 3000 volts
• High instantaneous pulse current	500 amperes
• Low trigger voltage (tp=2μs)	205 min. volts
• Low driving current	20 microamperes
• Short anode delay time	4 microseconds
• Minimum anode delay variation	0.4 microsecond
• Wide ambient temperature range	−55 to +85°C

Reliable products through
Advanced-Engineering

CBS tubes®

CBS-HYTRON, Danvers, Massachusetts
A Division of Columbia Broadcasting System, Inc.

IRE News and Radio Notes

G. W. BAILEY AWARDED HONORARY DEGREE BY LAWRENCE COLLEGE

George W. Bailey (A'38–SM'46–F'56), Executive Secretary of the Institute of Radio Engineers, has been awarded the honorary Doctor of Science degree by Lawrence College, Appleton, Wisconsin. The degree was presented by Douglas Knight, president of the college during graduation exercises Sunday, June 8. Mr. Bailey was presented for his degree by George Banta, Jr., president of the Lawrence board of trustees. President Knight, in conferring the degree, cited Mr. Bailey as follows:

"Of all the technical marvels bred by our age, radio is at once the most intimate and the most mysterious. You have set out to prove again that a Harvard man can do anything by becoming a master of that mysterious world. But you have combined with your special skill an equal talent in the world of human affairs. Chief among those who guided our use of scientific man power during the second war, executive of great effectiveness, and above all unique proprietor of station W2KH, Lawrence is happy to recognize in you a rare, essential fusion of the technical and the humane."

PROCEEDINGS ARE AVAILABLE

Proceedings of the Computers in Control Systems Conference, held Oct. 16–18, 1957 in Atlantic City, N. J., are now obtainable from the AIEE Order Dept., 33 W. 39 St., New York 18, N. Y. at $3.50 per copy. This conference was jointly sponsored by the IRE Professional Group on Automatic Control, AIEE Feedback Control Systems Committee, and the Instruments and Regulators Division of the ASME.

Call for Papers

1959 IRE NATIONAL CONVENTION

March 23–26, 1959

Waldorf-Astoria Hotel and New York Coliseum, New York, N. Y.

Prospective authors are requested to submit all of the following information by:

October 24, 1958

1. 100-word *abstract in triplicate*, title of paper, name and address
2. 500-word *summary in triplicate*, title of paper, name and address
3. An indication of the technical field in which the paper falls:

Aeronautical & Navigational Electronics
Antennas & Propagation
Audio
Automatic Control
Broadcast & Television Receivers
Broadcast Transmission Systems
Circuit Theory
Communications Systems
Component Parts
Education
Electron Devices
Electronic Computers
Engineering Management
Engineering Writing & Speech
Human Factors in Electronics
Industrial Electronics
Information Theory
Instrumentation
Medical Electronics
Microwave Theory & Techniques
Military Electronics
Nuclear Science
Production Techniques
Radio Frequency Interference
Reliability & Quality Control
Telemetry & Remote Control
Ultrasonics Engineering
Vehicular Communications

Note: Only considered are original papers not published or presented prior to the 1959 IRE National Convention; any necessary military or company clearance of paper must be granted prior to submittal.

Address all material to: Dr. George L. Haller, Chairman
1959 Technical Program Committee
The Institute of Radio Engineers, Inc.
1 East 79 Street, New York 21, N. Y.

Calendar of Coming Events and Authors' Deadlines*

1958

Spec. Tech. Conf. on Nonlinear Mag. and Mag. Amplifiers, Hotel Statler, Los Angeles, Calif., Aug. 6–8

Elec. Radio & Standards Conf., Univ. of Colo. and NBS, Boulder, Colo., Aug. 13–15

Int'l Conf. on Semiconductors, Univ. of Rochester, Rochester, N. Y., Aug. 18–22

WESCON, Ambassador Hotel and Pan-Pacific Audit., Los Angeles, Calif., Aug. 19–22

Emporium Section's Summer Seminar, Emporium, Pa., Aug. 21–23

Int'l Conf. for Analog Computations, Strasbourg, France, Sept. 1–7

Int'l Cybernetics Conv., Namur, Belgium, Sept. 3–10

Int'l Nuclear Elec. Conf. UNESCO House, Paris, France, Sept. 16–20

Nat'l Symp. on Telemetering, Americana Hotel, Miami Beach, Fla., Sept. 22–24

Indus. Elec. Conf., Rackham Mem. Audit., Detroit, Mich., Sept. 24–25

Annual PGBTS Symp., Willard Hotel, Washington, D.C., Sept. 26–27

Silicon-Carbide Conf., Air Force Cambridge Research Center, Bedford, Mass., Sept.

PGEWS Symp., New York City, Oct. 1–2

Radio Interference Reduction Conf., Armour Research Found., Chicago, Ill., Oct., 1–2

Symp. on Extend. Range and Space Commun., Lisner Audit., Geo. Wash. Univ., Washington, D.C., Oct. 6–7

IRE Canadian Convention, Exhibition Park, Toronto, Can., Oct. 8–10

Nat'l Electronics Conf., Hotel Sherman, Chicago, Ill., Oct. 13–15

1958 Int'l Systems Meeting, Penn-Sheraton Hotel, Pittsburgh, Pa., Oct. 13–15

PGCS Symp. on Aero. Communications, Hotel Utica, Utica, N. Y., Oct. 20–22

URSI Fall Meeting, Penn State Univ., Univ. Park, Pa., Oct. 21–22

Nat'l Simulation Conf., Dallas, Tex., Oct. 23–25

Natl. Soc. of Prof. Engrs., St. Francis Hotel, San Francisco, Calif., Oct. 23–25

EIA-IRE Radio Fall Meeting, Sheraton Hotel, Rochester, N. Y., Oct. 27–29

East Coast Aero. & Nav. Elec. Conf., Lord Baltimore Hotel and 7th Regiment Armory, Baltimore, Md., Oct. 27–29

1958 Electron Devices Meeting, Shoreham Hotel, Washington, D. C., Oct. 30–Nov. 1.

PGNS Mtg., Villa Motel, San Mateo, Calif., Nov. 6–7.

Conf. on Elec. Tech. in Medicine & Biology, Minneapolis, Minn., Nov. 12–14 (DL*: Oct. 1, J. Herrick, Inst. of Exper. Med., Mayo Clinic, Rochester, Minn.)

Atlanta Section Conf., Atlanta-Biltmore Hotel, Atlanta, Ga., Nov. 17–19

* DL = Deadline for submitting abstracts.

(Continued on page 15A)

Calendar of Coming Events and Authors' Deadlines*

(Continued from page 14A)

Conf. on Magnetism and Mag. Materials, Sheraton Hotel, Philadelphia, Pa., Nov. 17–20 (DL*: Sept. 1, H. B. Callen, Physics Dept., Univ. of Pa., Philadelphia, Pa.)
NEREM, Mechanics' Bldg., Boston, Mass., Nov. 19–20
Conf. on Elec. Techniques in Medicine and Biology, Minneapolis, Minn., Nov. 19–21
Acoustical Soc. of Amer., Chicago, Ill., Nov. 20–22
Elec. Computer Exhibition, Olympia, London, Eng., Nov. 28–Dec. 4
Eastern Joint Computer Conf., Bellevue-Stratford Hotel, Philadelphia, Pa., Dec. 3–5 (DL*: Sept. 15, F. M. Verzuh, M.I.T. Comp. Ctr., Cambridge 39, Mass.
Nat'l Symp. on Global Comm., Colonial Inn, Desert Ranch, St. Petersburg, Fla., Dec. 3–5
PGVC Annual Mtg., Hotel Sherman, Chicago, Ill., Dec. 4–5
Mid-Amer. Elec. Convention, Mun. Audit., Kansas City, Mo., Dec. 9–11

1959

Rel. & Qual. Control Nat'l Symp., Bellevue-Stratford Hotel, Philadelphia, Pa., Jan. 12–13
Natl. RQC Symp., Bellevue-Stratford Hotel, Philadelphia, Pa., Jan. 12–14
Seventh Region Conf., Univ. of New Mex., Albuquerque, N. M., Feb. 2–4
Solid-State Circuits Conf., Univ. of Pa., Philadelphia, Pa., Feb. 12–13 (DL*: Oct. 16, A. P. Stern, G. E. Co., Elec. Park, Bldg. 3, Syracuse, N.Y.)
Western Joint Computer Conf., Fairmont Hotel, San Francisco, Calif., Mar. 2–6 (DL*: Oct. 1, M. L. Lesser, IBM Research Lab., San Jose, Calif.)
IRE Nat'l Convention, Coliseum and Waldorf-Astoria, New York City, Mar. 23–26
Nuclear Cong., Cleveland, Ohio, Apr. 5–10
SW Regional Conf., Dallas, Tex., Apr. 16–18
New Tech. in Elec. Indus. Instr., Philadelphia, Pa., Apr. 20–21
Nat'l Aero. Elec. Conf., Dayton, Ohio, May 4–6
URSI Spring Meeting, Washington, D.C., May 5–7
Elec. Components Conf., Ben Franklin Hotel, Philadelphia, Pa., May 6–8
7th Reg. Tech. Conf., Univ. of N. M., Albuquerque, N. M., May 6–8
Joint Conf. on Auto. Tech., Pick-Congress Hotel, Chicago, Ill., May 11–13
Natl. Conf. on Prod. Tech., San Francisco, Calf., June 4–5
Int'l Conf. on Information Processing, Paris, France, June 15–20 (DL*: Oct. 1, A. L. Householder, Box 4999, Washington 8, D. C.
WESCON, San Francisco, Calif., Aug. 18–21
Int'l Congress on Acoustics, Stuttgart, Germany, Sept. 1–8
Natl. Symp. on Telem., San Francisco, Calif., Sept.

* DL = Deadline for submitting abstracts.

WESCON LISTS SPECIAL EVENTS

Once again, the Western Electronic Show and Convention is being held, this time at the Ambassador Hotel and Pan-Pacific Auditorium of Los Angeles, Calif. on August 19–22.

The convention is co-sponsored by the Los Angeles and San Francisco Sections of IRE Region 7 and the West Coast Electronic Manufacturers' Association.

WESCON committee activities will be directed by the WESCON board of directors with L. W. Howard as its chairman and executive committee with B. S. Angwin as its chairman. The 1958 convention director is W. E. Peterson, and H. P. Moore is serving as show director. The business manager, Don Larson, heads activities of the WESCON staff and is responsible for production of the events.

Forty-two technical sessions, including two special sessions, are on the four-day WESCON agenda. They will be held in all five major meeting rooms of the Ambassador Hotel concurrently each morning and afternoon. The combined capacity of the meeting rooms is 4700 persons.

In one of these two special sessions, six speakers will discuss "Biological Measurement Problems of Space Travel," under the chairmanship of Dr. Robert Tschirgi of U.C.L.A. on Wednesday evening, August 20. That afternoon, an invited-paper session on "Industry Looks at Fusion Power" is scheduled.

For the first time, 1958 technical program speakers will be guided by a special booklet prepared this year. It contains a concise series of suggestions on how to achieve the most effective presentations of papers, written by Norbert Lorenz, Joseph Cryden, Carl Kludt, and Mel Jones, working under the general supervision of the technical program committee headed by R. C. Hansen.

Possibly the most complete array of equipment for presentation of technical addresses—projectors and screens of different sizes, opaque, single-slide and slide-film projectors, recording devices, motion-picture equipment—will be immediately available to 1958 speakers.

Committees on visitors' housing and visitors' services will provide information, accommodations, and checking services at major hotels.

The WESCON exhibit at Pan-Pacific Auditorium will present about nine hundred electronic exhibits by more than seven hundred different companies.

The big auditorium will be augmented by four pavilions to accommodate the show. One entire pavilion will feature electronic production materials and equipment exclusively. Persons interested primarily in this field will find all production equipment in one place.

Throughout the show, wider aisles, 10 feet in width have been provided to insure easier viewing of exhibits and the elimination of "traffic jams."

In another pavilion will be housed the Future Engineers' Show, with outstanding student-scientists exhibiting their work. Invitations to participate have previously been extended throughout all Sections in IRE Region Seven. A luncheon and an awards banquet will be included and scholarship and savings-bond awards will be made.

Electronic devices of historical interest will be also displayed in a collection arranged by committee members working under the direction of D. C. Wallace, chairman.

Field trips to nine outstanding southern California locations have been confirmed by the committee headed by Burgess Dempster. Included is a visit to a "space chamber" operation, and to a new facility for static testing of large missiles. Also scheduled is a simulated SCA flight briefing and inspection of aircraft at March Air Force Base, and inspections of several electronic manufacturing and research centers in greater Los Angeles.

A visit to the Inhabited High Vacuum Laboratory at Litton Industries, Los Angeles, is scheduled as a part of WESCON's field-trip program. The laboratory simulates conditions that prevail 95 miles above the earth. Here Neils Jensen models suit used during experiments in the space chamber, which visitors will see.

Other WESCON special events range from a cocktail party, for which three major Ambassador rooms will be transformed into one giant party room, to an Art-in-Electronics exhibit which promises to present more works by "Sunday artists" than ever. The auction of the paintings, drawings, sculpture and craft pieces will benefit the WCEMA scholarship fund.

The traditional All-Industry Luncheon will climax WESCON activities August 22 in the Cocoanut Grove, which will also be the scene of a Distributor-Rep Conference extended this year to an all-day session. The conference will be held August 21.

Ladies who attend WESCON will enjoy a full program built on the theme of colorful early California and planned by a committee headed by Mrs. R. B. Leng. The feminine contingent will visit the art galleries of the Huntington Library following a luncheon at the Huntington-Sheraton in Pasadena, and Marineland and the Palos Verdes peninsula on another trip. An afternoon reception at the Ambassador and a luncheon at the Beverly Hills Hotel is also scheduled.

The Arrangements committee, headed by Spencer Varian, will maintain a master flow-chart of all WESCON activities to make sure that each event happens on time and with detailed preparation. A punch-card registration system is being prepared and possibly will include automatic read-out equipment for keeping running tabulations. Closed-circuit TV again will be used, both at the show and at the Ambassador Hotel.

1958 Western Joint Computer Conference Recently Convened

On May 6–8, the 1958 Western Joint Computer Conference, "Contrasts in Computers," was held at the Ambassador Hotel, Los Angeles, Calif. With every event's registration about half again as large as predicted, conference attendance came to a total of over 1800 people. A bonus feature of the technical program was the added technical session devoted to a paper describing the recently-announced French Gamma-60 computer.

Fifty exhibitors demonstrated recent components, equipment, techniques, and company progress in the eighty booths of the exhibit area. Following the conference, a one-day symposium on "Small Automatic Computers and Input/Output Equipment," was sponsored by the Los Angeles Chapter of the ACM, and attended by 350. Papers from eight manufacturers described their latest equipment.

Proceedings of the conference will be published in the late fall of 1958 and will be available to nonregistrants from the three cosponsoring societies: IRE, the Association for Computing Machinery, and the American Institute of Electrical Engineers. Proceedings of the symposium will be published at a later date by the ACM.

New Journal on Problems of Research Management Appears

The Industrial Research Institute, Inc. and Interscience Publishers announce, as a joint undertaking, a new journal, *Research Management*, devoted to discussions and solutions of problems of research management.

The journal will appear in four issues annually, and each issue will consist of approximately 64 pages. The subscription price is $7.50 per year.

Articles in *Research Management* will be contributed by representatives of the member companies of the Industrial Research Institute.

1959 Nuclear Congress Asks for Abstracts by October 1

The 1959 Nuclear Congress will be held at the Cleveland Auditorium in Cleveland, Ohio, April 5–10, 1959. As in the past, the Congress will be composed of the Nuclear Engineering & Science Conference, the Hot Laboratories & Equipment Conference, the Atomic Energy Management Conference, and the Atomfair.

Clarke Williams, chairman of the Nuclear Engineering & Science Conference, asks that prospective authors submit 300–500-word summaries of their papers to the IRE Representative to the Congress committee, L. G. Nierman, Graf, Nierman & Nierman, 141 W. Jackson Blvd., Chicago 4, Ill., before October 1. Papers presenting the most recent and outstanding developments in the nuclear field are solicited.

For further general information about the Congress interested persons should contact: T. A. Marshall, Jr., Engineers Joint Council, 29 West 39th St., New York 18, N. Y.

PROFESSIONAL GROUP NEWS

A comprehensive bibliography covering 2200 articles dealing with applications of electronics to medicine and biology, compiled by the Medical Electronics Center of the Rockefeller Institute, has recently been published by the IRE Professional Group on **Medical Electronics.** The bibliography includes both subject and author indexes. The *Bibliography on Medical Electronics* may be purchased at $2.50 per copy from the Institute of Radio Engineers, 1 East 79 St., New York 21, N. Y.

The Awards Committee of the Professional Group on **Ultrasonic Engineering** has selected two authors as the recipients of its 1957 and 1958 Best Paper Awards. They are J. E. May, Jr., whose paper on "Low Loss 1000 Microsecond Delay Lines" appeared in the PGUE TRANSACTIONS of August, 1956; and H. Epstein and O. B. Stram, whose paper on "A High-Performance Magnetostriction-Sonic Delay Line" appeared in the PGUE TRANSACTIONS of August, 1957.

OBITUARIES

Don G. Burnside (A'12–SM'46 (L)), an engineer associated with the Radio Corporation of America for 26 years, died recently in Clearwater, Fla.

From 1926 to 1931 he was employed by the engineering department of the Atwater Kent Company. In 1931 he entered the research and engineering department of the Radiotron Division of RCA at Harrison, N. J., and in 1942 he was transferred to the David Sarnoff Research Laboratories at Princeton, N. J. At the time of his death he was an engineer at the RCA Missile Test Project at Patrick Air Force Base, Fla. As a result of his work he was granted thirty United States and foreign patents on electrical and electronic devices.

Louis J. Link (A'30–VA'39–SM'57), chief engineer of WSUN, WSUN-TV, died recently at the age of 55.

Oldest member of the WSUN organization in point of service, Mr. Link watched over both stations from the time of their inception. He started with WSUN radio in 1927 and was one of the chief persons behind the development of television in this area. He at one time served as station manager for more than a year, held the title of assistant manager on several other occasions and served as acting manager a number of times.

He was Chairman of the IRE Florida West Coast Section at the time of his death. He was a member of the Florida Association of Broadcasters.

Mr. Link designed the two 500-foot radio and TV towers serving WSUN, and WSUN's television studio on St. Petersburg's Million Dollar Pier. When the city decided to put WSUN into the television field, Mr. Link was sent to confer with RCA Corporation executives, and the report he brought back to St. Petersburg's city manager was credited with making it possible for the city to open the first station in the Tampa Bay area, May 31, 1953.

During World War II when WSUN was on the air 24 hours a day, Mr. Link was a key figure in the statewide blackout signal system. He also helped wartime training of wireless students for the U. S. Signal Corps

National Symposium on Telemetering

SEPTEMBER 22–24, 1958, AMERICANA HOTEL, MIAMI BEACH, FLA.

The National Symposium on Telemetering, to be sponsored by the IRE Professional Group on Telemetry & Remote Control, will be held at the Americana Hotel, Miami Beach, Fla., September 22–24.

A classified meeting, sponsored by the Air Force Missile Test Center at Patrick Air Force Base, Cocoa, Fla., will be held September 25. Clearance must be obtained in advance through regular channels. Transportation from Miami to Patrick Air Force Base can be arranged at the Americana Hotel.

Monday, 9:30 A.M.–12 Noon

Digital Techniques

Chairman: L. W. Gardenhire, Director Astrionics Div., Radiation, Inc.

A Novel Technique for Direct Digital Conversion of Pulse-Width Multiplexed Data, F. T. Chambers, Applied Science Corp. of Princeton.

Automatic Reduction of Large Volume Test Data, I. S. Oscar, Minneapolis-Honeywell Regulator Co.

A Transistor-Driven Magnetic-Core Memory Using Non-Coincident Current Techniques, R. L. Koppel, Lockheed Missiles Systems Div.

A Range Time Decoder, H. A. Kirsch, Ramo-Wooldridge Corp.

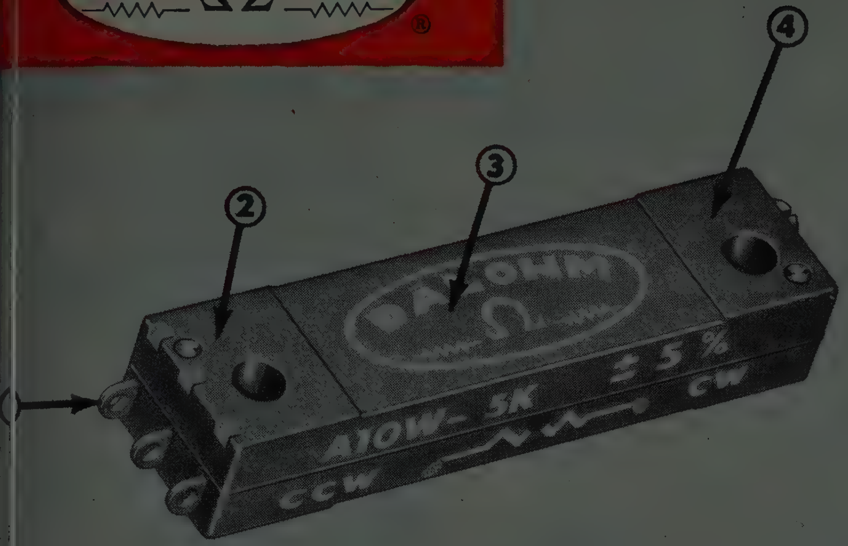
Transistorized Telemetry Components

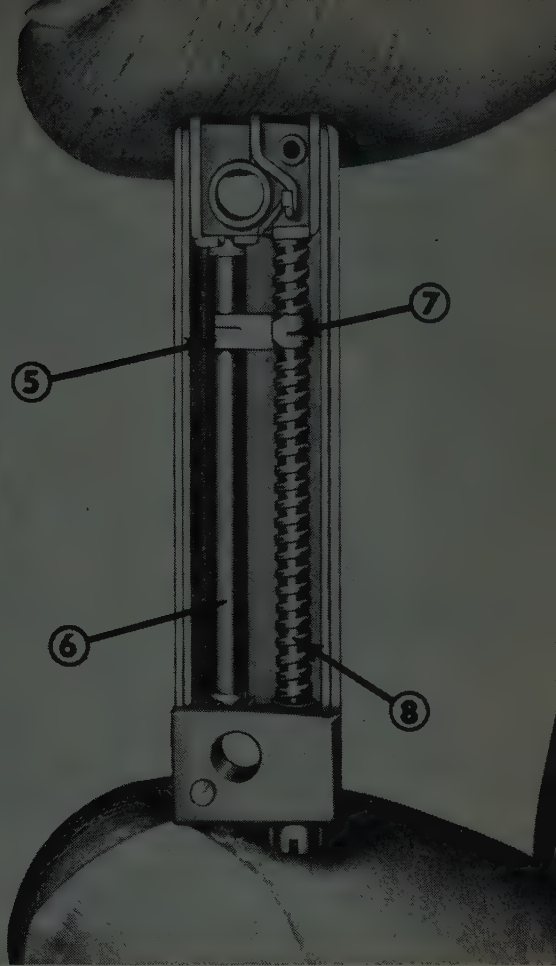
Chairman: C. E. Gilchriest, Jet Propulsion Labs., Calif. Inst. Tech.

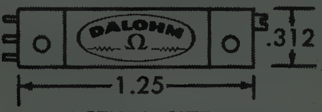
A Transistorized Analog Signal Converter for Missile Telemetry, R. P. Kittel, Hoover Electronics.

You can depend on

DALOHM







ACTUAL SIZE

Dalohm A10-W Trimmer assures 100% reliability!

Three terminal types available: Standard solder lug type shown ɔove, printed circuit type, and with insulated wire leads. All terminals e treated to facilitate easy soldering.

Mounting pads, an integral part of case, provide secure mounting base uneven surface. Mounted with two #2-56 screw holes for either acked or multiple arrangements.

Legible markings and dimensional uniformity.

Case and unit are built to withstand severe shock, vibration and celeration.

Novel slider design assures good contact.

Precision winding by the most advanced techniques assures excellent solution and long life.

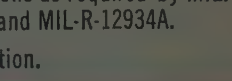
Trimmer adjustment has a unique design, providing self-locking tion to assure stable settings under extreme environmental conditions.

Trimmer adjustment screw, which can be adjusted throughout a 25 rn range, is completely insulated from circuit. Special safety clutch revents internal damage from over-excursion during adjustment.

- Rated at 1 watt up to 70° C. ambient temp.
- Resistance range: 10 ohms to 30K ohms.
- Standard tolerance ±5%, closer tolerance available.
- Resolution as low as .07%.
- Sub-miniature size and space saving configuration.
- Mounted individually or stacked assemblies with standard 2-56 screws.

B11-W Trimmer Potentiometer

This is a commercial grade DALOHM trimmer potentiometer, retaining the desirable characteristic of the A10-W, at economical cost.

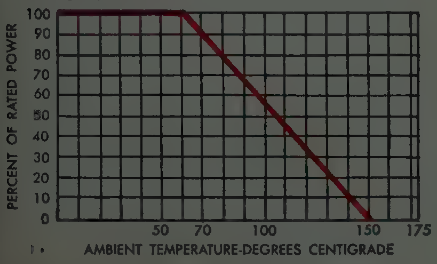


- Rated at 1 watt, derating to 0 at 150°
- Standard resistance range: 10 ohms t 100K ohms, with forty standard value
- Standard tolerance: ±10%.
- Sub-miniature size: .220 X .312 X 1.250 inches.

Exceeds trimmer potentiometer specifications as required by MIL. SPECS MIL-R-19A, MIL. STD.-202A, MIL-E-5272A and MIL-R-12934A.

Request bulletin R-32 for complete information.

A10-W TRIMMER DERATING CURVE



JUST ASK US...

DALOHM line includes a complete selection of miniature precision power resistors (wire wound and deposited carbon), precision wire wound miniature trimmer potentiometers, and collet fitting knobs. Write for free catalog.

If none of DALOHM standard line meets your need, our engineering department is ready to help solve your problem in the realm of development, engineering, design and production. Just outline your specific situation.

DALE
PRODUCTS,
INC.
1302 28th Ave.
Columbus, Nebr., U.S.A.

Analysis and Performance Characteristics of Transistorized Subcarrier Oscillator Circuits for Airborne Telemetering, M. M. Wilkinson, Texas Instruments, Inc.

A Transistorized Voltage Controlled FM Subcarrier Oscillator, A. M. Chwastyk, Applied Physics Lab., Johns Hopkins Univ.

Completely Transistorized Current/Voltage Controlled Oscillator, W. H. Foster, Avionics Div. of Aerojet-General Corp.

A Transistorized Calibrator for Missile Telemetry, O. B. King, Army Ballistic Missile Agency.

Afternoon, 2:00–4:40 P.M.

TELEMETRY IN SPACE

Chairman: D. G. Mazur, Naval Res. Labs.

Advanced Telemetry Techniques, Hans Scharla-Nielsen, Radiation, Inc.

Radiation and Propagation of Telemetry Signals During Hypersonic Re-Entry—E. Langberg, K. Baldwin, and J. Yos, Avco Manufacturing Corp.

Some Factors in Instrumenting a Missile Nose Cone During Re-Entry, Milton Berkowitz, General Electric Co.

Modulations Imposed on a Radio Signal By Satellite Motions, A. T. Waterman, Jr., Stanford Electronics Labs.

Satellite Environment via 1 MW Subcarrier Oscillators, F. M. Riddle, Jet Propulsion Labs., Calif. Inst. Tech.

NEW COMPONENTS IN TELEMETRY

Chairman: L. Lawrence, Redstone System Coordination Office, Chrysler Corp.

A Real Time Complex Wave Analyzer, C. W. Spindler, Jr., General Electric Co.

Phase-Locked Demodulation in Telemetry Receivers, D. D. McRae, Radiation, Inc.

FM Capture Performance and Its Consideration in Receiver Design, A. W. Emmons, Ramo-Wooldridge Corp.

A Miniaturized Synchro Data Converter with a Two-Speed Output Designed for Airborne Telemetering Applications, R. B. Owen, Universal Match Corp.

A Transistor Telemetering System For Conservation Research, John Althouse, Armour Research Foundation.

Tuesday, 9:30 A.M.–12 NOON

DATA RECORDING AND PROCESSING

Chairman: Jack Becker, A. C. Spark-Plug, Div. of General Motors Corp.

Automatic Digital Readout System for Telemetry, E. J. Telander, Radiation, Inc.

An Unique Digital Analog Data Recording and Processing System for Flight Testing, B. E. Applegate, General Electric Co.

New Design Philosophies in Dynamic Data Handling Systems, J. J. Dover, Ampex Corp.

A Compact Telemetry Data Recorder, Andrew Malcolm, Centronix, Inc.

Instrumentation for Airship Flight Test, R. Kramer, Goodyear Aircraft Corp. and W. Glass, Applied Science Corp. of Princeton.

Data Processing with Magnetic Tape Recorders, Boyd Thompson, Ampex Corp.

NEW RADIO FREQUENCY TECHNIQUES AND PROBLEMS

Chairman: C. A. Strom, Jr., Directorate of Communications, Rome Air Development Center, Griffiss Air Force Base.

Miniature High Performance FM Receivers for Telemetry and Command Guidance, Charles Rosen, Tele-Dynamics, Inc.

Automatic Control of Power in a Scatter Communications System, G. S. Axelby and E. F. Osborne, Westinghouse Electric Corp.

Radio Frequency Link Equipment for 2200 Megacycle Telemetering, M. S. Redden, Jr. and H. Herman, Gen. Electronic Labs.

A Terminal Ballistic Altitude Indicator, F. Enge, American Machine & Foundry Co.

Afternoon, 2:00–4:30 P.M.

DYNAMIC TESTING IN THE SPACE AGE

Chairman: D. F. Mattson, Lockheed Aircraft Corp.

A Pulse Position Telemetry System, L. Weisman and E. S. Teltscher, Ford Instrument Co.

Hypervelocity Telemetry Experiments at the Arnold Engineering Development Center, M. K. Kingery, Aro, Inc.

Instrumentation for Impact Testing By Means of Sleds, Darrell Gilliam, Avco Manufacturing Corp.

Collection and Presentation of Vibration Data, W. A. Schwarzmann, North American Aviation, Inc.

Telemetering with Magnetic Modulators, H. L. Stiltz, The Martin Co.

MODULATION—METHODS IN TELEMETRY

Chairman: K. M. Uglow, Consulting Engineer, Silver Spring, Md.

Designers Dilemma—Electronic or Mechanical Multiplexing, M. M. Kranzler, Applied Science Corp. of Princeton.

Comparison of the Performance of PAM-FM and FM-FM Telemetry Systems, D. Hochman, Lockheed Missile Systems Div.

An Experimental Airborne PAM-FM Telemeter Package for Missile Applications, T. D. Lusk, Lockheed Missile Systems Div.

The Ground Station of a PAM-FM Telemetry System, F. F. Fulton, Jr. and S. A. Schwartz, Lockheed Missile Systems Div.

Triple-FM—A Practical Method for Increasing the Capacity of Telemetering Systems, W. F. Janeway, Aerophysics Development Corp.

Wednesday, 9:30 A.M.–12 NOON

THE INSTRUMENTATION OF OUTER SPACE

Chairman: G. S. Shaw, Engineering Radiation, Inc.

Advanced Space Instrumentation Techniques, R. V. Werner, Cubic Corp.

Multichannel FM/FM Telemetering System, L. Katz, D. I. Kosowsky, and C. R. Hurtig, Hycon Eastern, Inc.

Transistorized S-Band Beacon System, E. Y. Politi, Lockheed Missile Systems Div.

Radio Techniques as Applied to Space Technology, L. P. Yeh, Westinghouse Electric Corp.

Data Collection Problems in Second Generation Ballistic Missiles, L. Sackett, Northrop Aircraft Co.

RECENT TECHNICAL ADVANCES IN COMMUTATORS

Chairman: M. V. Kiebert, Jr., Consolidated Electrodynamics Corp.

A High Level Magnetic Core Commutator, M. E. North and J. B. Crank, Texas Instruments, Inc.

Resampling Technique Increases Life and Rejects Common Mode Interference in Low Level Pulse Width Multicoder, J. A. Ruddiman and W. S. Wydro, Applied Science Corp. of Princeton.

A New Miniature Automatic Pulse Demultiplex Set, Leonard Finkel, Tele-Dynamics, Inc.

Low Level Magnetic Commutator, D. C. Kalbfell, Kalbfell Electronix.

I.D.L.'s Miniature, Low Level Commutator, C. A. Logan, Instrument Development Labs.

Afternoon, 2:00–4:30 P.M.

NEW TELEMETRY SYSTEMS

Chairman: P. J. Randolph, Jr., Instrumentation Development, Applied Physics Labs., Johns Hopkins Univ.

A Simultaneous Non-Interfering Single Channel Servo and Voice Transmission System, C. A. Crafts and M. D. McFarlane, Robertshaw-Fulton Controls Co.

The Cricket Beacon—A Precision Beacon for Tracking Small Beacons and Drones, J. S. Spira, W. L. Maxson Corp.

A Simplified PCM Telemetering System, H. K. Schoenwetter, Hoover Electronics Co.

A Modular Concept In Telemetry Data Acquisition Systems, I. P. Magasiny, Tele-Dynamics, Inc.

New Techniques and Components for Industrial Telemetry and Remote Control, S. M. Kurzet and H. A. McGee, United Electrodynamics.

TIME DIVISION MULTIPLEXING SYSTEMS

Chairman: C. H. Doersam, Jr. Sperry Gyroscope Co.

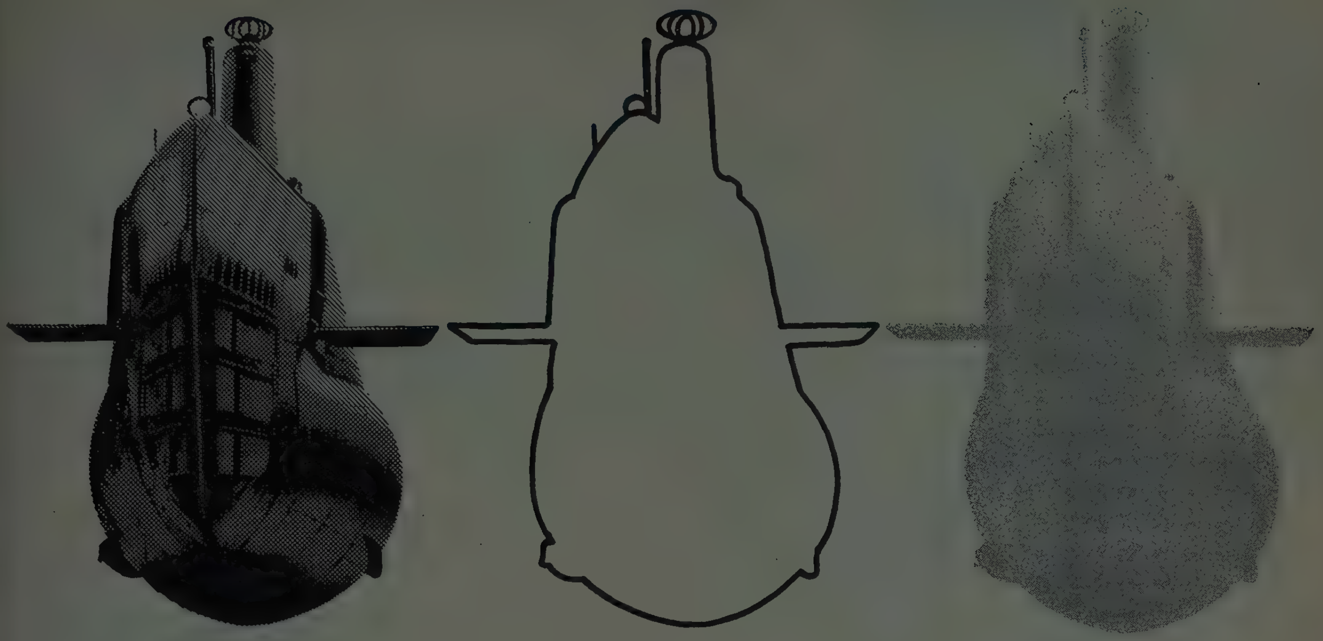
Precision PDM/FM Telemetering System, H. S. Goldberg and C. Pilnick, Consolidated Avionics Corp.

PDM/FM/FM on Lower Subcarrier Frequencies, F. E. Rock, Applied Science Corp. of Princeton.

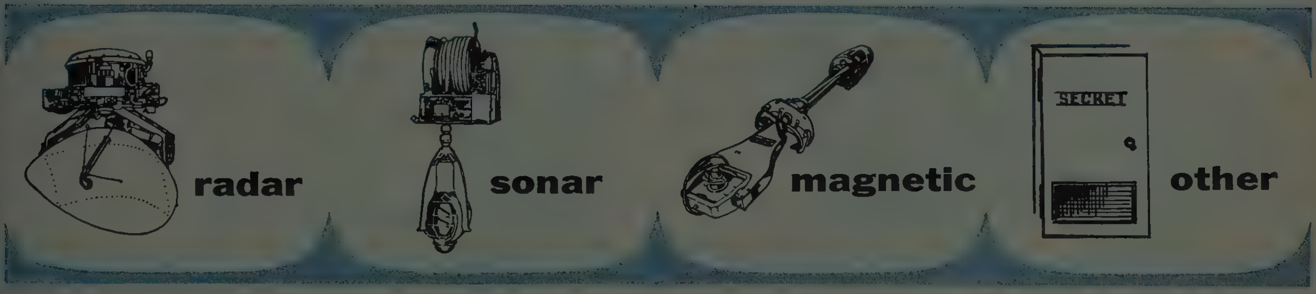
Pulse Code Modulations of Commutated Subcarrier Channels, T. D. Warzecha, Convair-Astronautics.

A Transistorized All-Electronic Low-Level Pulse Width Multicoder, J. A. Riedel, Jr., Appl. Science Corp. of Princeton.

in antisubmarine warfare, it has to be . . .



YES or NO . . . not MAYBE!



It takes a lot of faith in your radar, sonar and/or magnetic detection equipment to leave an area with a "clean" stamp . . . even more faith than it takes to believe the blip that shouts "sub below." Such confidence-building equipments are not developed overnight . . . indeed, the technology spawning this gear at Texas Instruments dates back nearly thirty years to similar techniques in pinpointing subsurface mineral wealth. Since its entry into this complex field, TI has supplied literally thousands of detectors to the free world's navies . . . *operational* means of locating, tracking, and triggering counter-attacks against the subs that swim the sea.

For detailed information on operational as well as advanced ASW gear now under development, properly cleared military or industrial personnel write or wire for appointments to: SERVICE ENGINEERING . . .

TEXAS INSTRUMENTS
INCORPORATED
6000 LEMMON AVENUE DALLAS 9, TEXAS

apparatus division

systems management — reconnaissance, airways control, anti-submarine warfare, anti-missile, countermeasures, airborne early warning, navigation, attack control, missile systems, engine control.

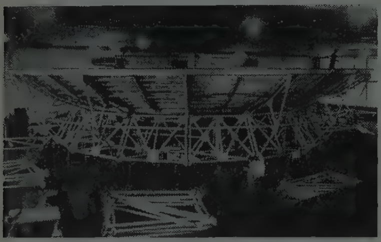
equipments — radar, infrared, sonar, magnetic detection, computers, timers, telemetering, intercom, microwave, optics, detector cells, engine instruments, transformers, time standards, and other precision devices.

research/design/development/manufacture

NEWS New Products

60 and 90 Foot Parabolas

The General Bronze Corp., 711 Stewart Ave., Garden City, N. Y., announced the development of two new antenna designs which will be designated as their "Sky-Chief" paraboloid reflector.



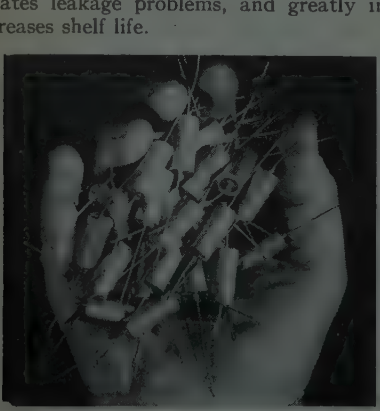
The 60 foot diameter antenna is said to have the highest survival specification yet designed or manufactured in the industry. A survival point of 150 mile an hour wind loading or 120 mile an hour winds with three inches of ice, is claimed for this unit.

These reflectors have been designed for adaptation to the proprietary General Bronze pedestal and servo systems for applications as radio telescopes or satellite and missile tracking antenna systems.

These rugged designs will bear the designation "Sky-Chief 60" or "Sky-Chief 90" and are offered to the industry with varied combinations of associated equipment to best meet the application specification requirements.

Solid Tantalum Capacitor

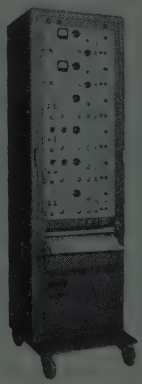
A complete line of solid tantalum capacitors that will withstand vibrational acceleration up to 40 g's at frequencies from 5 to 2,000 cps and temperatures up to 125° C has been announced by **Kemet Co., Div. of Union Carbide Corp.,** P.O. Box 6087, Cleveland 1, Ohio. With high capacitance per unit volume, the capacitors are made by compressing finely powdered tantalum metal into plugs that are then hermetically sealed in cylindrical metal cans. Absence of a liquid electrolyte eliminates leakage problems, and greatly increases shelf life.



"Kemet"* solid tantalum capacitors are available in capacitances ranging from 5 to 120 μf at working voltages from 6 to 30 volts at 85° C. Other ratings can be provided on special order. Immune to the effects of humidity and salt spray, the capacitors are extremely stable with respect to capacitance, dissipation factor, and leakage current over wide ranges of voltages, and temperatures ranging from as low as $-80°$ C up to 125° C. This upper temperature limit is claimed to be approximately 40° C above other tantalum capacitors. Life tests in excess of 10,000 hours at rated voltage have revealed negligible changes in performance characteristics.

*Registered TM.

6-Channel Direct Writing System

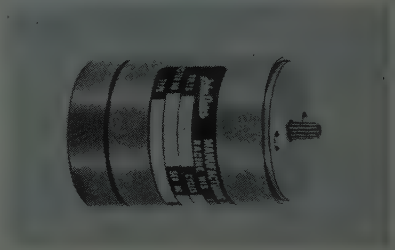


A new space-saving packaging method is now used for 6-channel Model 150 series direct-writing oscillographic recording systems designed by **Sanborn Co., Industrial Div.,** 175 Wyman St., Waltham 54, Mass. A single vertical, mobile cabinet contains the Model 156-5466 basic assembly, comprised of six driver amplifier-power supply units and 6-channel recorder assembly. To complete the system, the user adds any of 12 optional, interchangeable plug-in "150" preamplifiers.

The six driver amplifier-power supply units, which accept the interchangeable plug-in preamplifiers, occupy 42 inches of panel space above the recorder assembly. Overall dimensions of the vertical, mobile cabinet are 78 high×22 wide×25 inches deep. Recorder location places the chart at a convenient height for viewing and making notations. The system also provides all characteristic "150" features, including 1 per cent overall linearity; current feedback driver amplifiers and regulated power supplies for each channel; clear, inkless recordings in true rectangular coordinates by heated stylus on plastic-coated permapaper charts; individual stylus heat controls; nine chart speeds from 0.25 to 100 mm/sec.; choice of optional Preamplifiers including ac-dc, carrier, servo monitor, dc coupling, log audio, low level, stabilized dc, ac wattmeter, rms volt/ammeter, 400 cps frequency deviation, frequency meter and triplexer. Further data and complete specifications are available on request from the firm.

Coming soon!
The 1959
IRE DIRECTORY

60 and 400 cps Reversible Motor



A new versatile Size 11 airborne quality fine instrument type synchronous reversible motor which can be connected to either 60 or 400 cps operation is now available from **John Oster Manufacturing Co., Avionic Div.,** 1 Main St., Racine, Wis. Pullout torque at 60 cps and 1800 rpm is 0.15 ounce/inches and at 400 cps and 12,000 rpm is 0.085 ounce/inches. This is achieved by using a 1.0 μf capacitor for 60 cps operation or a 0.1 μf capacitor for 400 cps. Input voltage is 115 for both 60 and 400 cps. Type 11A-8011-01 is a 60 cps motor designed to meet MIL-E-5272, is rated at 12 watts input and weigh 4.25 ounces.

Fixed Wire Resistors

A new line of smaller, modular, permanently stable, 100 per cent tested, low temperature coefficient bobbinless precision wire fixed resistors which recently completed laboratory tests show far exceed the proposed MIL-R-93B spec has been developed by **Chicago Telephone Supply Corp.,** Elkhart, Ind. Floating element con-

(Continued on page 24A)

Raytheon — World's Largest Manufacturer of Magnetrons and Klystrons

ENGINEERING STRENGTH

This towering figure represents 3,300 Raytheon people at your service, helping to develop and produce magnetrons, klystrons and special purpose tubes—the most complete line in the industry.

The heart of this Raytheon division is our famous Research and Development Laboratory with 1,065 specialists, *of whom 207 are professional engineers.*

Put this dependable source of engineering manpower to work on your problems. Call on Raytheon's Application Engineering Service. Write for complete data booklet. There is no cost or obligation.

RAYTHEON MANUFACTURING COMPANY

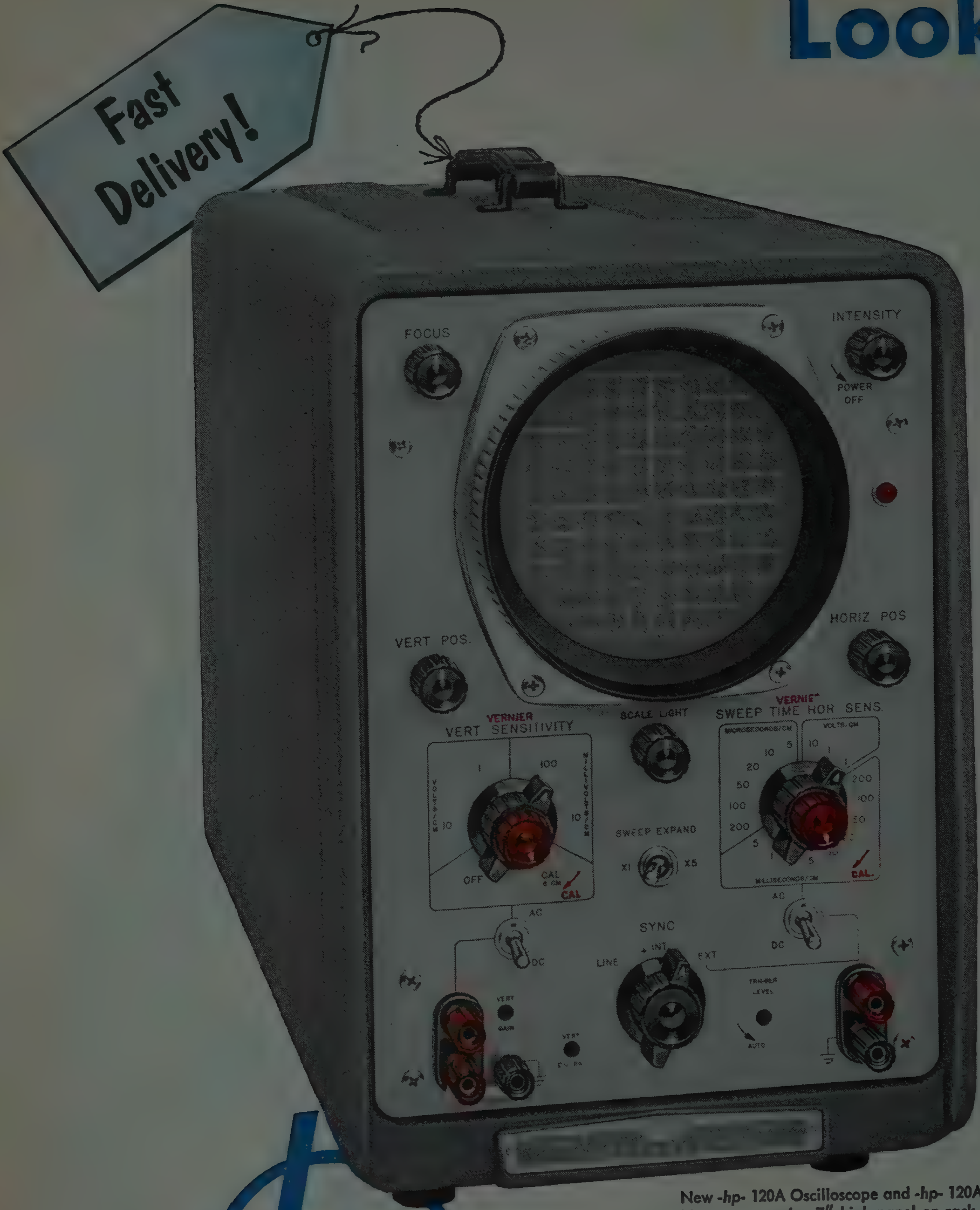
Microwave and Power Tube Division
Section PT-09, Waltham 54, Massachusetts

Excellence **RAYTHEON** *in Electronics*

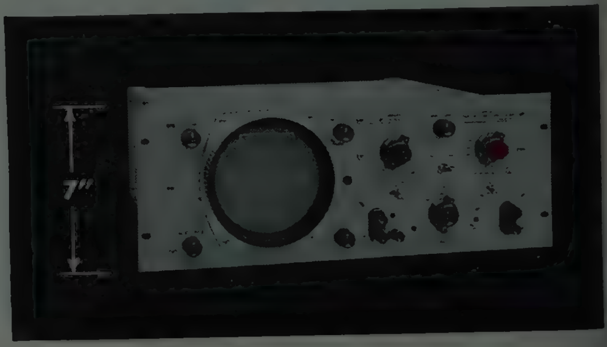
Regional Sales Offices: 9501 W. Grand Avenue, Franklin Park, Illinois
5236 Santa Monica Blvd., Los Angeles 29, California

Raytheon makes: Magnetrons and Klystrons, Backward Wave Oscillators, Traveling Wave Tubes, Storage Tubes, Power Tubes, Miniature and Sub-Miniature Tubes, Semiconductor Products, Ceramics and Ceramic Assemblies

Look at


Fast Delivery!
FOCUS
INTENSITY
POWER OFF
VERT POS.
HORIZ POS
SCALE LIGHT
VERNIER
VERT SENSITIVITY
VERNIER
SWEEP TIME HOR SENS.
SWEEP EXPAND
X1
X5
OFF
CAL
SYNC
LINE
INT
EXT
AC
DC
TRIGGER LEVEL
AUTO

New -*hp*- 120A Oscilloscope and -*hp*- 120AR Rack Mount Oscilloscope. Note space-saving 7″ high panel on rack mount instrument.



this all-new -*hp*- $435 oscilloscope!

- Check the simple panel.
  Few controls—faster, easier measuring!
- Check the specs; DC to 200 KC, automatic trigger, high stability, accuracy
- An -*hp*- thoroughbred; finest quality, rugged, dependable, portable

Let's spell out this new -*hp*- oscilloscope very fast.

It's medium priced, deliberately engineered for simple operation, accuracy and dependability. Lightweight, only 32 pounds.

There's absolutely no compromise with quality or features to bring you the attractive price.

It has automatic triggering, no adjustment over entire range. Yet a front panel adjustment can cut out automatic triggering and base line to provide a bright, steady trace for photography. Only -*hp*- offers this.

The oscilloscope has sweep speed range from 1 μsec/cm to 0.5 sec/cm. Speeds are slow enough for mechanical or medical work, fast enough for most rapid transients. There's a "times-5" sweep expansion and a vernier to give continuous control of sweep speed. There are 15 calibrated sweeps, 1-2-5 sequence.

Instantaneous automatic synchronizing is available on any internal or external voltage; instrument may also be triggered by line voltage.

The DC-coupled vertical amplifier has a pass band of 200 KC. Calibrated vertical and horizontal amplifiers have identical bandwidths for phase measurements. High sensitivity permits working directly from transducers in many cases.

High stability is insured by regulated power supplies, including a transistor regulated vertical amplifier filament supply.

The 5AQP1 cathode ray tube comes out easily through the front panel: you change filters in 30 seconds. The 5AQP1 is the same CRT used in more expensive -*hp*- 'scopes. It provides linear response, uniform trace intensity and perfect focus over the entire tube face. Fully illuminated graticule, CRT beam adjusting lever.

You might call the -*hp*- 120A the first *multi-purpose deluxe* oscilloscope ever offered at medium price. Here is calibrated performance for precision lab work and brute ruggedness for the production line. -*hp*- 120AR Rack Mount is ideal for fixed installations and test console applications.

Call your -*hp*- engineer for a demonstration, or write direct for details. Fast delivery!

BRIEF SPECIFICATIONS

SWEEP

Trigger selector: internal, external, line.

Triggers automatically on 0.5 cm. display internal or 2.5 volts peak-to-peak external. Displays base line in absence of signal. No sync controls required.

15 calibrated sweeps in 1-2-5 sequence, 5 microseconds/cm to 200 milliseconds/cm ±5% accuracy; vernier 2.5/1 range (lowers sweep speed). 5 times sweep expansion, applicable on all ranges.

VERTICAL AMPLIFIER

Bandwidth: DC Coupled — DC to 200 KC.
AC Coupled — 2 cycles/sec to 200 KC.

4 calibrated sensitivities: 10 mv/cm, 100 mv/cm, 1 v/cm, 10 v/cm; ±5% accuracy; 10/1 vernier.

Balanced input available on 10 mv/cm range.

Internal amplitude calibrator provided.

HORIZONTAL AMPLIFIER

3 calibrated sensitivities: 0.1 v/cm, 1 v/cm, 10 v/cm; 10/1 vernier.

Bandwidth same as vertical amplifier.

GENERAL

Cathode Ray Tube: 5AQP1 with 2500 v accelerating potential.

Intensity Modulation: terminals on rear.

Power Input: approximately 130 watts.

All DC power supplies regulated.

Size: Cabinet, 9¾" x 15" x 21¼"; 32 lbs.
Rack, 19" x 7" x 18"; 31 lbs.

Price: -*hp*- 120A or 120AR (Rack Mount), $435.00.

Data subject to change without notice.
Prices f.o.b. factory.

HEWLETT-PACKARD COMPANY
4620D Page Mill Road
Palo Alto, California, U.S.A.
Cable HEWPACK • DAvenport 5-4451
Field engineers in all principal areas

4620

-hp- provides industry's newest, most complete oscilloscope line!

Important Features of AMPHENOL MINNI E CONNECTORS

actual size

1

The "E" construction of AMPHENOL's miniature, multi-contact electrical connectors pass a *tough*, new *altitude-moisture resistance test* which accurately simulates performance conditions in new aircraft and missiles. Connectors are submerged in salt water and altitude-cycled to 80,000 ft., to 65,000 ft. and then returned to room ambient pressure. Cycle lasts one hour; test is comprised of ten cycles. At the end of the test AMPHENOL **MINNI E's** have a minimum insulation resistance of 1000 megohms, approximately ten times greater than that acceptable under MIL-C-5015C after moisture.

2

MINNI E's have *stainless steel* bayonet slots and pins, providing greater durability and eliminating the wear encountered with "hardcoat" and similar surface treatments of softer base metals.

3

Both #16 and #20 size socket contacts in **MINNI E** connectors *resist test prod damage*. The entering end of the socket has a one-piece stainless steel hood that excludes the entrance of a pin .005" larger than the diameter of the mating male contact.

AMPHENOL's Authorized Industrial Distributors stock MINNIE and other standard components, provide immediate service.

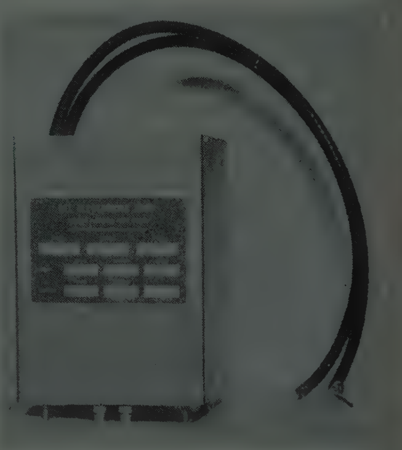
AMPHENOL ELECTRONICS CORPORATION
chicago 50, illinois

(Continued from page 20A)

struction firmly embeds resistance elements and contacts in epoxy resin, reducing space factor and eliminating wire strain, bobbin and winding form. Design flexibility permits grouping many resistors in a single unit. High temperature exposure and short time overload tests are run on all units before shipment. Average change under most environmental conditions and shelf life is 0.5 per cent. A 5 ppm/°C temperature coefficient is available but 30 ppm/°C is standard for resistance under 2000 ohms and 20 ppm/°C for resistance of 2000 ohms and over, whereas MIL-R-93B permits 75 ppm/°C and 30 ppm/°C respectively. Short time overload is 0.05 per cent maximum (MIL-R-93B permits 0.5 per cent), moisture resistance 0.1 per cent maximum, 1000 megohms insulation resistance (MIL-R-93B permits 1.0 per cent, 100 megohms, load life at 125°C or 85°C for 500 hours 0.15 per cent maximum (MIL-R-93B permits 0.5 per cent), salt water immersion cycling 0.03 per cent maximum (MIL-R-93B permits 0.5 per cent), temperature cycling 0.05 per cent maximum (MIL-R-93B permits 0.2 per cent), low temperature storage, low temperature operation and high (145°C) temperature exposure are each 0.05 per cent maximum (MIL-R-93B permits 1.0 per cent) and acceleration, shock and vibration are each 0.02 per cent max (MIL-R-93B permits 0.1 per cent). Resistors are guaranteed to be in tolerance under normal conditions of measurement.

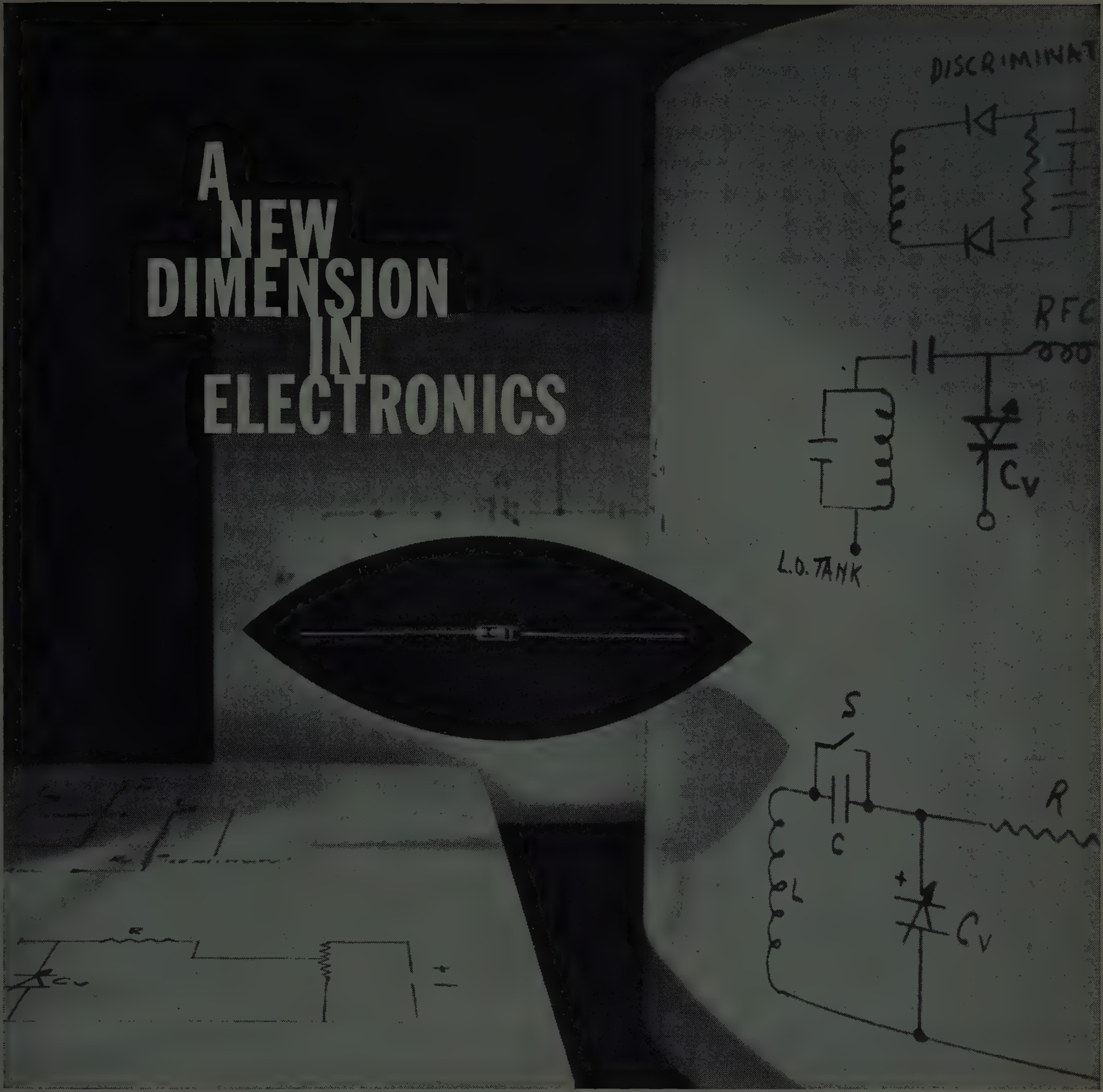
High Voltage Supplies

Shown below is Model 10-1-1 of a new series of power supplies manufactured by **Del Electronics Corp.**, 521 Homestead Avenue, Mount Vernon, N. Y. It will deliver 10 kv dc at 1.25 ma with an rms ripple of 0.25 per cent at 60 cps or 0.04 per cent at 400 cps. The dimensions are 3×3½×5½ inches high.



These supplies feature reversible polarity, shielded polyethelene output cables and selenium rectifiers. The entire unit is embedded in an epoxy resin and hermetically sealed. Extremely compact design for mounting on chassis is one of its outstanding characteristics.

(Continued on page 128A)



The Hughes silicon capacitor is a new kind of device whose full impact upon semiconductor electronics has yet to be determined. Most certainly, the silicon capacitor uncovers an entire realm of possibilities. Desirable equipment not now existing can be made for the first time. And, in every instance, bonus benefits of reduced size and weight plus greater simplicity result.

Our brochure, "The Hughes Silicon Capacitor," discusses this series and many of its applications in detail. For your copy, please write:

Hughes Products, Semiconductor Division,
International Airport Station, Los Angeles 45, Calif.

WESCON Exhibits booths 1401-2.

Some Suggested Applications:

Non-Mechanical Tuning: The effect upon tuned circuit design is tremendous. Hughes silicon capacitors replace bulky air condensors and permit remote-control tuning at the end of a long wire. With these capacitors, instantaneous and non-mechanical "signal seeking" features can be designed into tuned circuits.

Automatic Frequency Controls: Here the silicon capacitors replace a reactance tube. Output voltage from the discriminator varies the voltage on the silicon capacitor—hence, the local-oscillator frequency—to correct for any frequency drift.

Dielectric Amplifiers: Operation is based on the amplitude modulation of a high-frequency carrier source by a Hughes silicon capacitor, and on the subsequent demodulation and filtering at the output.

Also: Pulse Circuits, Frequency Modulation, RC Oscillators, Modulators, Electronically Controlled Filters.

HUGHES
SEMICONDUCTORS

Creating a new world with ELECTRONICS

HUGHES PRODUCTS

© 1958, Hughes Aircraft Company

QUICKER—
MORE ACCURATE—MORE
RELIABLE CIRCUIT DESIGN

CONDUCTANCE CURVE DESIGN MANUAL

by Keats A. Pullen, Jr., Eng., D.

This vacuum tube working manual for the engineer thoroughly ties together circuit equations and the concept of small signal parameters for use in circuit design. It provides a group of data, in table and graph form, so organized that it helps the user design circuits which function in the manner desired, *with a minimum of readjustment.* With the manual, the engineer can use small signal parameters to predict large signal performance with the following benefits:

- makes it possible to optimize a design so that a given performance can be obtained with minimum tube element dissipation by permitting point-by-point determination of dynamic operating conditions anywhere within a tube's rating. Life and circuit reliability are enhanced and experimental readjustment is minimized.
- clearer understanding of in what manner circuit performance changes when any circuit parameters are varied. Makes it evident that when a required performance can't be obtained without operating the tube near or at its peak, another tube type with greater power handling capability should be chosen.
- aids in the design of conservatively rated circuits for greater reliability.

MANUAL DIVIDED INTO THREE PRINCIPAL SECTIONS

① explanation of the special curves and their application in typical R-C amplifier designs.

② tables useful in making tube substitutions and tables to simplify the selection of tubes for given applications.

③ a special set of conductance curves for more than 70 of the most representative vacuum tube types used in all services. Includes low power and high power tubes, triodes and pentodes, and several mixer tubes.

#210 128pp., 8½x11", spiral stiff cover binding **$4.25**

BASICS OF DIGITAL COMPUTERS

by John S. Murphy

Written by a man with many years of experience in the computer field, this 3 volume "picture-book" training course lays the foundation of digital computer system concepts from which any individual computer can be studied. Excellent foundation for training on all types and all brands of digital computers.

Volume 1—provides digital computer system background—binary data representation, automatic arithmetic, programming and control.

Volume 2—introduces basic building blocks of the logical systems and presents details of transition from communication electronics to computer electronics. Using the fundamentals of communication electronics as a basis, it highlights the elemental uses of tubes, diodes and magnetic cores in digital computers. Ties together the logical building blocks and elemental circuits through typical examples combining their use.

Volume 3—deals with major units in a digital computer from a systems point of view. Discusses magnetic drums and core types of memory, timing pulses, control units, input and output. Static and dynamic types of registers including shift registers covered.

Basics of Digital Computers is ideal background for engineers, laboratory assistants as well as other technical personnel who wish to broaden their knowledge of this new, rapidly expanding field. The fundamentals of digital computers are presented idea-by-idea, page-by-page permitting the reader to build his knowledge step-by-step. Specially selected illustrations support the text and make it crystal-clear. At least ONE big illustration on each page!

#196, 3 volumes, soft cover set, only **$6.95**

#196-H, all 3 vols. in single cloth binding, **$7.95**

Add state and city tax where applicable.
Canadian prices 5% higher.

10-DAY UNCONDITIONAL
MONEY-BACK GUARANTEE

Write
Dept. IR-8

JOHN F. RIDER PUBLISHER, INC.
116 West 14th Street, New York 11, N. Y.
In Canada: Charles W. Pointon, Ltd., 6 Alcina Avenue,
Toronto, Ontario

IRE People

J. R. Anderson (M'52), formerly director of physical research at National Cash Register Company, Dayton, Ohio, has joined Stanford Research Institute as manager of the computer laboratory.

In his new position, Mr. Anderson will plan and direct programs in the research and development of computer techniques, switching theory, high speed digital circuits, magnetic logic circuits, and special purpose computing devices. He will be responsible for three research groups: circuit systems, special devices and computer development.

At the National Cash Register Company, where he had been since 1956, Mr. Anderson directed activities in research analysis, systems research, magnetics research and solid state physics. For ten years prior to that time, he was associated with Bell Laboratories, where he carried on research on data storage and logic devices using ferroelectrics. Five patents have been issued in his name based on this work.

A graduate of Denison University (Ohio), Anderson received his M.S. degree in physics in 1939, and an M.S. degree in electrical engineering in 1940, both from the University of Michigan.

Mr. Anderson is a member of the Acoustical Society of America and Phi Beta Kappa

❖

Henri Busignies (M'42–SM'43–F'45), president of Federal Telecommunication Laboratories, the research and development division of the International Telephone and Telegraph Co., received the honorary degree of Doctor of Science at the recent 42nd commencement exercises of Newark College of Engineering, held at the city's Mosque auditorium. He is the eighth person to have received the degree since the college first granted honorary doctorates in 1919.

H. BUSIGNIES

Born in Sceaux, France, in 1905, Mr. Busignies received his electrical engineering degree in 1926 from the Institute Normal Electro Technique in Paris. An authority in the fields of electronic direction finding equipment and air navigation, radar, and radio communications, he is noted for having invented, in 1926, the first automatic direction finder for aircraft. He presently holds more than a hundred patents in direction finding systems, instrument landing systems, and early radar design including Moving Target Indicator radar.

Mr. Busignies, who had joined the company's Paris laboratories in 1928, escaped from German-occupied France in 1940, and in 1941 participated in the establishment of Federal Telecommunication Laboratories here in the United States. He was named technical director of the Laboratories in 1949, and, as the responsible executive in charge of research and development, directed the development of the tactical air navigation radio direction system known as TACAN, and other electronic systems. He became executive vice-president of the Laboratories in 1954, and has served as president since 1956.

In 1941 and 1942 he served on a committee of experts to plan a course of twenty-six lectures in the field of ultra-high frequencies for the Engineering Science Management Defense Training Programs at Newark College of Engineering, designed to upgrade engineers and scientists in ultra-high-frequency practices in the early days of radar. He also presented a lecture of his own in the series, which was repeated several times.

He received the Lakhovsky Award in 1926 from the Radio Clubs of France for the first automatic radio compass; he designed the "Huff Duff" direction finder system during the war and received the U. S. Navy Certificate of Commendation in 1947. In 1948 he was awarded the President's Certificate of Merit for his contributions to science in World War II and for his activities on the National Defense Council.

He is a member of the American Institute of Electrical Engineers, the advisory committee of the Aeronautical Radio, Electronic Industries' Association; French Engineers in the United States, the Society of French Civil Engineers, and a life member of the Societe pour l'Avancement des Sciences.

❖

Vanguard Associates, Inc. of Indialantic, Melbourne, Fla., announces the following personnel changes: **J. D. Dillon** (A'47–M'52) from President to Chairman of the Board; Cdr. **J. J. Edgerly** (A'49–SM'55), USNR, from Vice-President, Sales to President; and **W. R. McPherson** (A'55) moves from District Manager, Miami, to Vice-President, Sales.

Vanguard Associates is the manufacturers' representative for fifteen national electronic equipment firms in seven southeastern states.

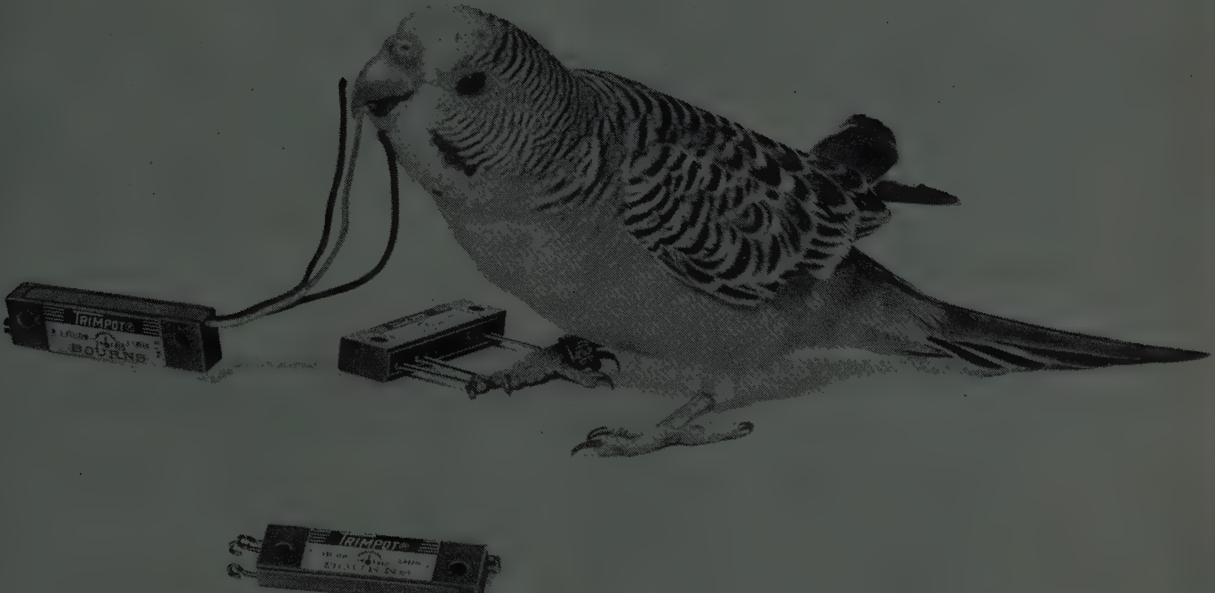
❖

(Continued on page 28A)

ONLY ONE POTENTIOMETER THIS SMALL GIVES YOU THESE 5 FEATURES

Mount 16 units per square inch—cross-section only 0.190″ x 5/16″

1. High temperature operation—to 175°C.
2. Humidity-proof—new plastic molding technique makes possible a smaller, fully-sealed potentiometer exceeding specifications of MIL-STD-202A, 10 days.
3. Power rating: one watt at 70°C.
4. Standard mounting holes on one-inch centers.
5. Easier, more accurate settings—25 turn screw driver adjustment gives you 33 times the adjustability of single-turn potentiometers, easy repeatability. Settings are stable and self-locking.



SEE US AT THE WESCON SHOW, BOOTH 1104

IT'S THE NEW BOURNS TRIMPOT® MODEL 224

Available immediately from factory or distributors' stock with insulated stranded leads, solder lugs or printed circuit pins. Resistances: 100Ω to 50K. Exceeds military shock and vibration specs. For data on the new Model 224 TRIMPOT write to:

BOURNS Laboratories, Inc. P.O. Box 2112F, Riverside, California

EXCLUSIVE MANUFACTURER OF TRIMPOT® AND TRIMIT® • PIONEERS IN POTENTIOMETER TRANSDUCERS FOR POSITION, PRESSURE AND ACCELERATION

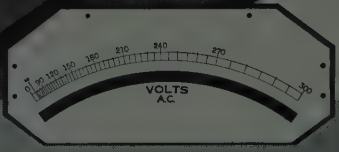
"The accuracy of an instrument is no better than its calibrated scale."

SENSITIVE RESEARCH SCALE DRAWING MACHINE

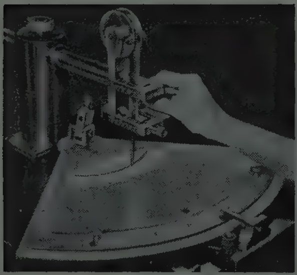
For the precise hand-drawing of Electrical Indicating Instrument scales.

See it at WESCON!
Booth Nos. 1309-1310

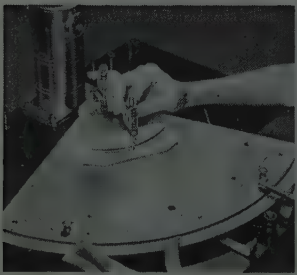
MODEL SCAMA



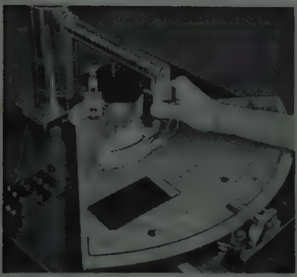
Typical AC-DC Polyranger scale



Drawing scale calibration lines



Drawing scale arcs



Printing scale numerals

The Model SCAMA is designed for use by *military and industrial personnel engaged in the repair and maintenance of electrical indicating instruments.* It is an exact duplicate of the scale drawing machines used in SRIC's own production laboratories for the past 31 years.

Wherever the efficient in-plant repair of indicating instruments is a necessity, the economies of owning a scale drawing machine are readily apparent. The best craftsmen, furnished with the finest electrical standards, are still inadequately equipped if they lack the means necessary to "wrap the job up" by restoring the instrument to its original accuracy. It is incongruous that the one thing that is usually missing is the equipment to match or re-draw the instrument's scale to its pointer deflection. The Model SCAMA is furnished complete with all necessary accessories to draw and print any flat scale plate to infinite accuracy. Included is a 40-hour course of instruction in its use given at SRIC's plant.

If you are an organization or group actively engaged in the repair of electrical indicating instruments, we urge you to investigate further the potentialities of the Model SCAMA.

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N.Y.

Symbol of Quality

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

(Continued from page 26A)

J. P. Hagen (A'37–SM'47–F'54) Director of Project Vanguard, has been paid tribute by Boston University with two distinctive honors.

On June 8th, the university conferred upon its "distinguished alumnus" the honorary degree of Doctor of Science. In presenting the degree, the president of Boston University, cited Dr. Hagen for his outstanding achievements in science and bestowed the honor upon him as "a worthy son whose investigations have advanced human knowledge of the upper atmosphere and astrophysics."

The Director of Project Vanguard also received from the Boston University Alumni Association, an award for "outstanding public service."

It was presented in recognition of his "invaluable contribution to the future of mankind in the Space Age and for displaying in accomplishment a quality of patience, perserverance, industry, and humanity in the highest American tradition."

Dr. Hagen joined the Naval Research Laboratory in 1935, serving as head of the R-F Research Section from 1935 to 1954. In 1954, he was named the first superintendent of the newly-formed Atmosphere and Astrophysics Division, which position he will resume at the conclusion of Vanguard.

He is the author of numerous papers in the general field of astrophysics, and has actively participated in international meetings of radio astronomers and physicists, as well as Navy-sponsored eclipse expeditions, the most recent one having been to Sweden in 1954. His major fields of scientific interest include: properties of quartz crystals, microwave radio circuits, radio astronomy, and upper air research.

Born in Amherst, Nova Scotia, Canada, Dr. Hagen received the degrees of Bachelor of Arts in physics from Boston University (1929), Master of Arts in physics from Wesleyan University (1931), and Doctor of Philosophy in physics from Georgetown University (1949).

He is a fellow of the American Academy of Arts and Sciences; a member of the American Astronomical Society, International Astronomical Union, Washington Academy of Sciences, National Science Foundation Advisory Panel on Radio Astronomy, Research Society of America, Sigma Xi; member and past chairman of Advisory Committee of Associated Universities, Inc.; Secretary of U. S. National Committee of International Union of Scientific Radio; and Vice-Chairman of URSI International Commission V.

❖

H. W. Henkels (M'53) is appointed manager of the advanced development engineering section at Westinghouse Electric Corp.'s semiconductor department at Youngwood, Pa. Dr. Henkels received his B.S.C.E. degree from the University of Pennsylvania in 1943 and subsequently

Continued on page 34A)

The Knight Who Went to the Devil

In East Merovingia, the peasants like to tell the story of the ambitious knight who offered to trade his soul to the Devil. The knight asked what he would receive in return.

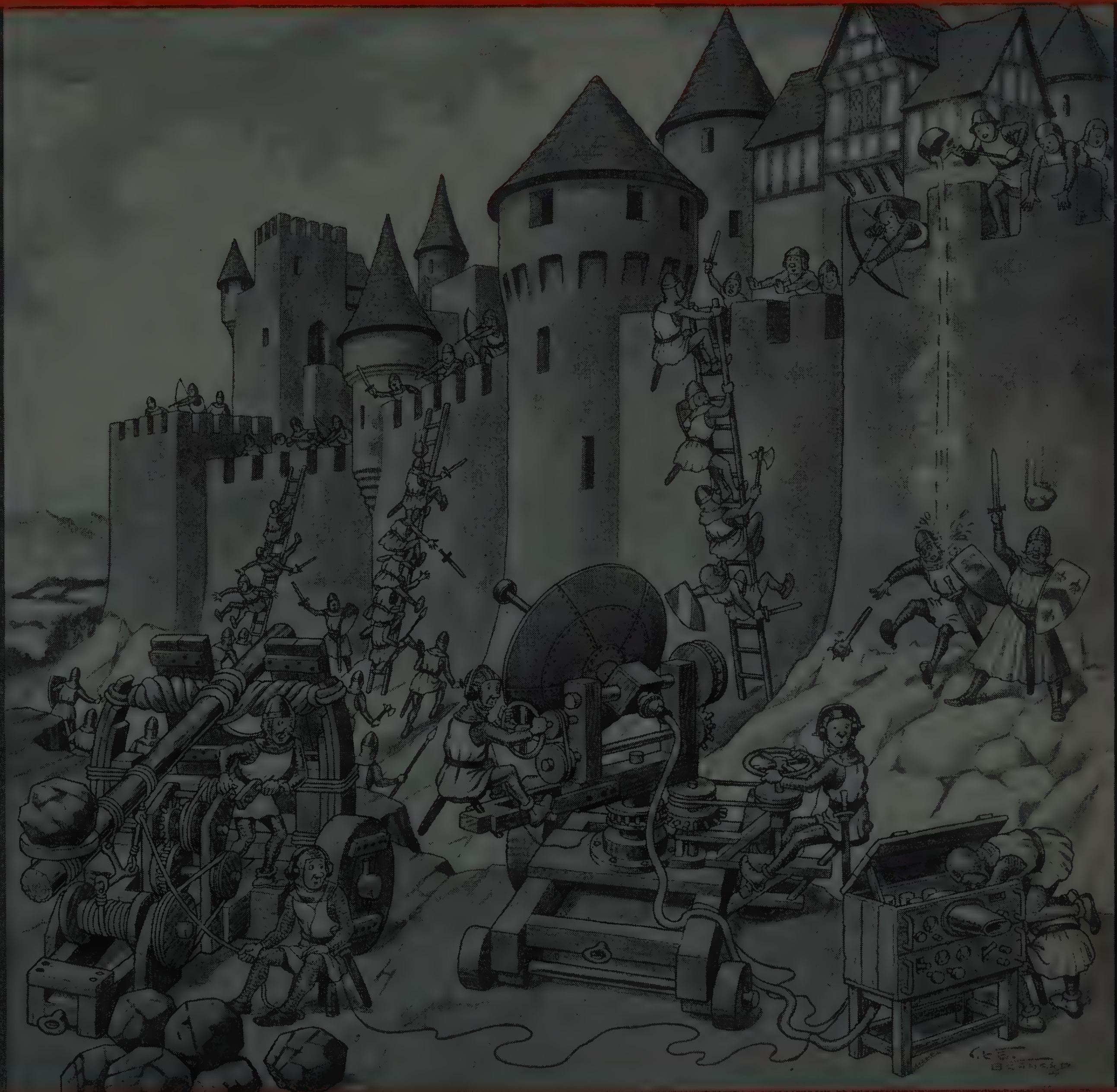
The Devil, realizing that one way to catch a rabbit is to hide behind a tree and make a noise like a carrot, offered to help him overthrow the King. "I will make you one of the crowned heads of Europe," the Devil said. And he promised to fashion for the knight a super-weapon — a radar controlled missile launcher — to make his victory doubly sure.

against the King, his troops were routed. The radar failed utterly. His missiles were so misguided, the day was lost.

The Devil later explained away his trickery by saying that even he couldn't make radar work without Bomac tubes. "And anyway," he said, "I lived up to my part of the bargain." (For proof, see picture. The knight, on the extreme right with sword, is, indeed, about to be crowned.)*

The Merovingian peasants will tell you that this wasn't the first, nor the last time a man of arms has lost his head tripping over the Devil's tale.

No. 8 of a series . . . **BOMAC LOOKS AT RADAR THROUGH THE AGES**



*[illegible]

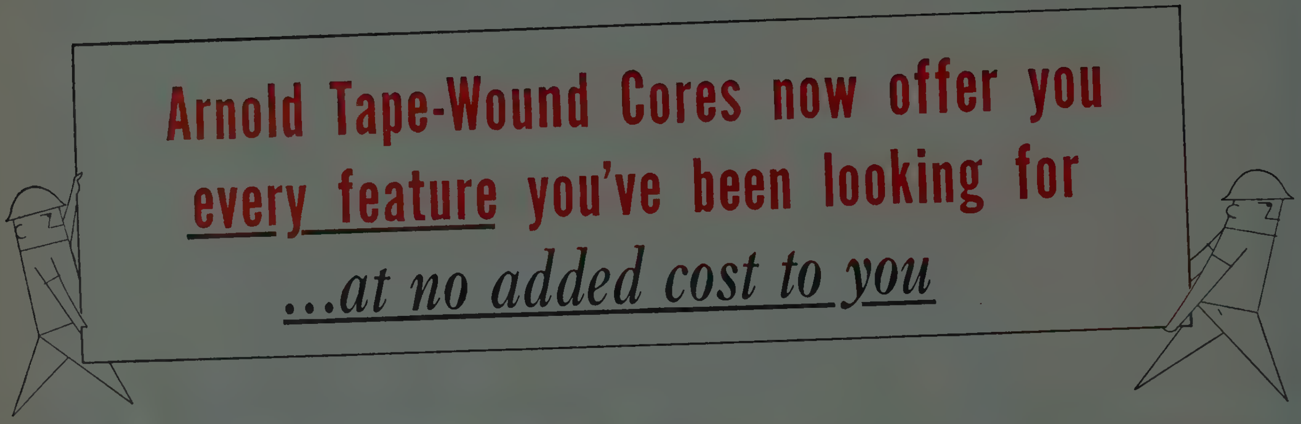
WRITE FOR FREE SIX PAGE FOLDER **Bomac LABORATORIES, INC.,**
Salem Road, Beverly, Massachusetts

Leaders in the design, development and manufacture of TR, ATR, Pre-TR tubes; shutters; reference cavities; hydrogen thyratrons; silicon diodes; magnetrons; klystrons; duplexers;

Offices in major cities—Chicago • Kansas City • Los Angeles • Dallas • Dayton • Washington • Seattle • San Francisco • Canada: R-O-R Associates Limited, 1470 Don Mills Road, Don Mills,

IT'S NEW AND NEWS

from ARNOLD



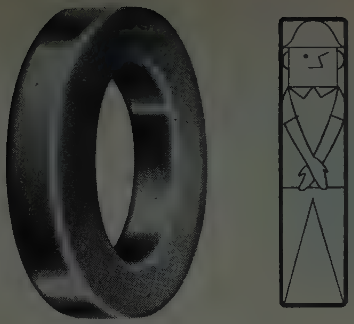
Arnold Tape-Wound Cores now offer you every feature you've been looking for

...at no added cost to you

1

NEW COMPACTNESS in Aluminum-cased Cores

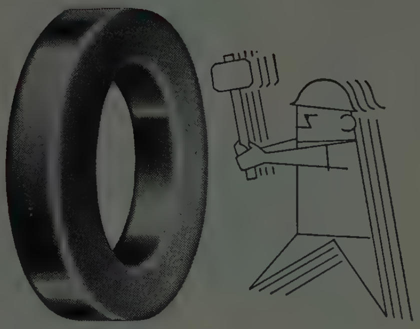
Now you can build your designs around the last word in improved tape cores of high-permeability materials. Arnold 6T Cores incorporate a new type of aluminum core box construction, with overall dimensions smaller than older types of aluminum cases, and comparable in size with ordinary plastic-cased cores. *Result:* along with the distortion-free strength of the aluminum case, that resists winding stresses, you now get the compactness and miniaturization possibilities you've wanted.



2

HERMETICALLY SEALED, with Built-in Protection against Shock and Vibration

Magnetic properties of Arnold 6T Cores have the most complete protection available on the market. The cores are surrounded by an inert shock absorbent inside the cases, and then hermetically sealed: your best assurance of trouble-free performance, a strong consideration where the service involves long periods of standby. Inherent in the design, of course, is the further guarantee that you can vacuum-impregnate your coils.



3

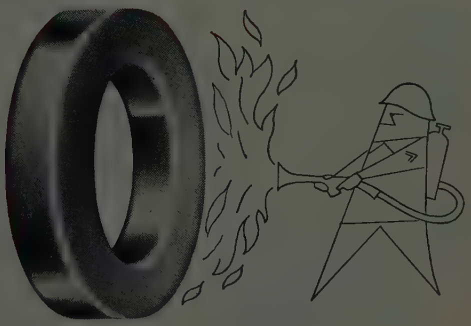
1000-VOLT BREAKDOWN GUARANTEED!

The revolutionary new type of core box construction developed for Arnold 6T Tape Cores employs a strong, inert covering for which 1000-volt breakdown is guaranteed. This covering possesses a hard gloss finish, and gives a suitable radius on all corners. The elimination of sharp corners insures against cutting through the insulation of the winding wire. The hard, non-cold-flowing finish protects against the wire cutting through the case covering, a double guarantee against shorted wiring.

4

MEETS MILITARY "SPECS" for Operating Temperatures and Temperature Rise

Arnold's new type of hermetically-sealed aluminum core box construction fully meets the requirements of military specifications Mil-T-5383 or Mil-T-7210, wherever applicable. This involves a positive guarantee that the case construction will withstand ambient temperatures to 170°C, and a 25°C temperature rise.

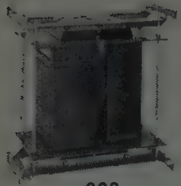


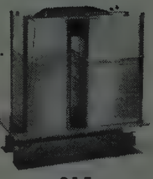
Arnold 6T Tape Cores will be available in all standard sizes, and special sizes may be made to order... all guaranteed for size, hermetic seal, dielectric strength and temperature of operation.

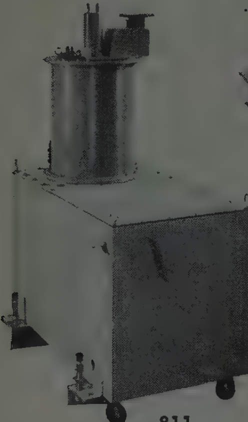
WSW 7250

THE ARNOLD ENGINEERING COMPANY

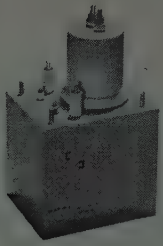
Main Office & Plant: Marengo, Illinois
Repath Pacific Division Plant: 641 East 61st Street, Los Angeles, Calif.
District Sales Offices:
Boston: 49 Waltham St., Lexington Los Angeles: 3450 Wilshire Blvd.
New York: 350 Fifth Ave. Washington, D.C.: 1001-15th St., N.W.

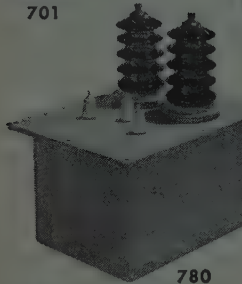

803


815

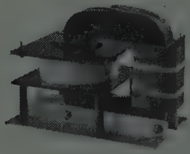

811

701


721


780

228


917

814

2001

2000

carad corporation

2850 bay road • redwood city, california
emerson 8-2969

designers and manufacturers of pulse transformers and associated pulse components

KLYSTRON AND TWT PULSE TRANSFORMERS

Cat. No.	Secondary Voltage KV	Secondary Current Amps	Turns Ratio	Pulse Width μs	Duty Cycle	Secondary Winding
803	235	102	1: 8.5	6 — 10	.00168	Monofilar
815	200	165	1:18.5	3	.0011	Monofilar
808	200	7	1:25	6	.0001	Monofilar
809	165	157	1:11	1 — 5	.00273	Monofilar
811	150	120	1:13	6	.0025	Monofilar
800	135	87	1:13	6 — 12	.003	Monofilar
801	115	78	1: 8.8	9	.0026	Monofilar

MAGNETRON PULSE TRANSFORMERS

Cat. No.	Secondary Voltage KV	Secondary Current Amps	Turns Ratio	Pulse Width μs	Duty Cycle	Secondary Winding
780	65	184	1:-5.5	6	.002	Monofilar
743	32	80	1: 4.5	.8 — 8.0	.001	Bifil. 3.0A
742	32	80	1: 4.5	.4 — 4.0	.001	Bifil. 3.0A
741	32	80	1: 4.5	.2 — 2.0	.001	Bifil. 3.0A
733	32	53.4	1: 5.5	.8 — 8.0	.001	Bifil. 3.0A
732	32	53.4	1: 5.5	.4 — 4.0	.001	Bifil. 3.0A
731	32	53.4	1: 5.5	.2 — 2.0	.001	Bifil. 3.0A
784	30	60	1:-1.75	.3	.0014	Monofilar
785	30	60	1: 1.75	.3	.0014	Bifil. 16A
723	24	35.6	1: 4.1	.8 — 8.0	.001	Bifil. 2.0A
722	24	35.6	1: 4.1	.4 — 4.0	.001	Bifil. 2.0A
721	24	35.6	1: 4.1	.2 — 2.0	.001	Bifil. 2.0A
787	22	27.5	1: 5	1.0	.001	Bifil. 3A
786	19	16	1: 5	.5	.001	Bifil. 3A
713	16	17.8	1: 4.7	.8 — 8.0	.001	Bifil. 1.50A
712	16	17.8	1: 4.7	.4 — 4.0	.001	Bifil. 1.50A
711	16	17.8	1: 4.7	.2 — 2.0	.001	Bifil. 1.50A
703	6	5	1: 5.5	.8 — 8.0	.001	Bifil. 1.25A
702	6	5	1: 5.5	.4 — 4.0	.001	Bifil. 1.25A
701	6	5	1: 5.5	.2 — 2.0	.001	Bifil. 1.25A

HIGH INSULATION VOLTAGE TRANSFORMERS

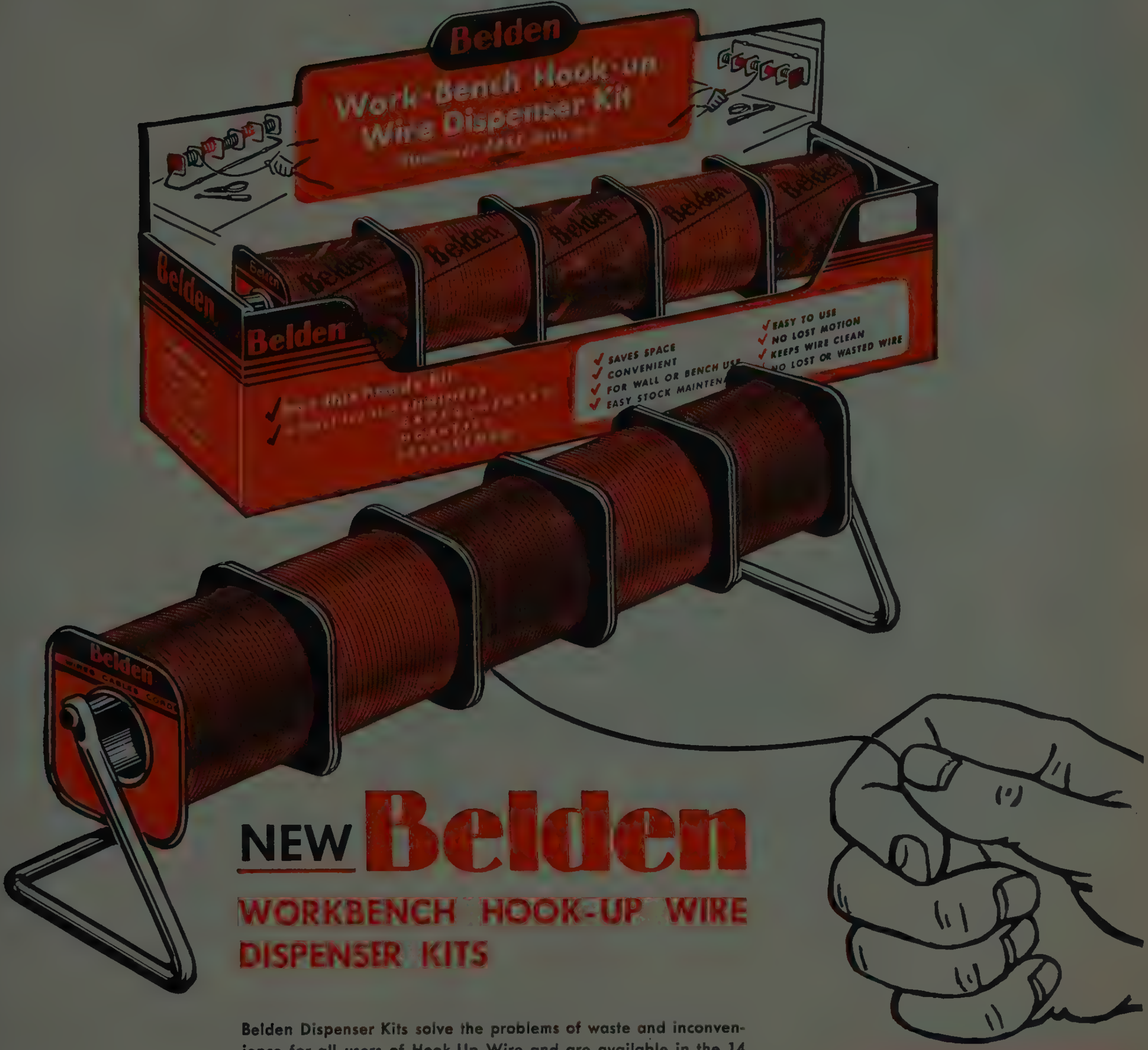
Cat. No.	Insulation Voltage	Primary	Secondary	Operation
814	220 KV DC	4 KV Pulse	8 KV pulse — 5 μs	Oil
227	37 KV DC	1 KV Pulse	1 KV pulse — 10 μs	Oil
228	20 KV DC	.25 KV Pulse	1 KV pulse — 10 μs	Air
916	260 KV Pulse	208 V-60 cps	9 V — 80 amps	Oil
911	260 KV Pulse	115 V-60 cps	12 V — 75 amps	Oil
919	200 KV Pulse	208 V-60 cps	16 V — 10 amps	Oil
917	150 KV Pulse	115 V-60 cps	8.5 V — 35 amps	Oil
912	60 KV Pulse	115 V-60 cps	10 V — 25 amps	Oil

Pulse Packages for Magnetrons and Klystrons

Packages are designed to meet specific electrical and mechanical requirements. Packages contain pulse transformer, pulse forming network, charging reactor, and filament transformer.

4913

R and D Labs
Engineers...
Servicemen...
Hobbyists...


Belden
Work-Bench Hook-up
Wire Dispenser Kit
✓ SAVES SPACE
✓ CONVENIENT
✓ FOR WALL OR BENCH USE
✓ EASY STOCK MAINTENANCE
✓ EASY TO USE
✓ NO LOST MOTION
✓ KEEPS WIRE CLEAN
✓ NO LOST OR WASTED WIRE
Belden
WIRE CABLES CORDS

NEW Belden

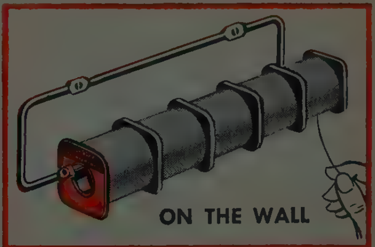
WORKBENCH HOOK-UP WIRE DISPENSER KITS

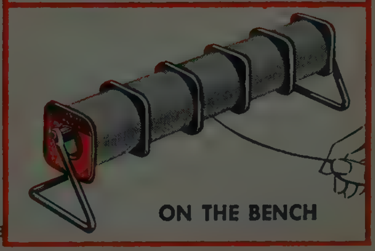
Belden Dispenser Kits solve the problems of waste and inconvenience for all users of Hook-Up Wire and are available in the 14 most popular assortments of Vinyl, Vinyl-Nylon, Textile, and Teflon* insulated wire for every requirement.

Each kit contains an assortment of Hook-Up Wire colors and types plus a portable metal dispenser rack for workbench or wall mounting. The dispenser rack provides a complete, compact, and convenient wire department for every working area at the user's finger tips, simplifies user Hook-Up Wire stock maintenance, and helps keep wire clean and orderly while keeping the workbench neat and efficient. Available at all Belden jobbers.

* Du Pont trademark

SEE US IN BOOTHS 1114 and 1115 WESCON SHOW, Los Angeles, August 19-22


ON THE WALL

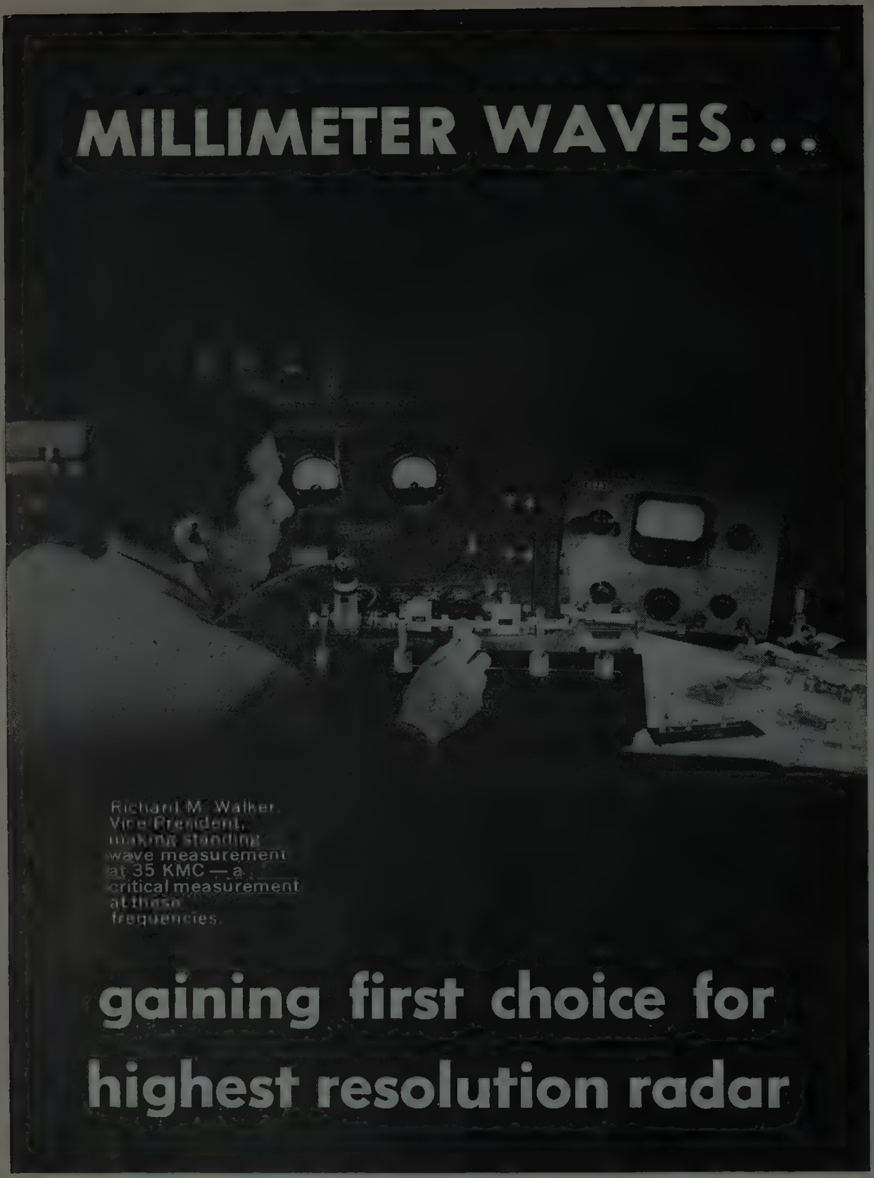

ON THE BENCH

One Wire Source for Everything Electrical and Electronic

Magnet Wire • Lead Wire • Power Supply Cords,
Cord Sets and Portable Cord • Aircraft Wires
Electrical Household Cords • Electronic Wires
Welding Cable • Automotive Wire and Cable

Belden
WIREMAKER FOR INDUSTRY
SINCE 1902
CHICAGO

08A01G8


MILLIMETER WAVES...
Richard M. Walker, Vice President, making standing wave measurement at 35 KMC — a critical measurement at these frequencies.
gaining first choice for highest resolution radar

Airborne radar now rivals optical performance; automatic ground approach systems, radio astronomy, passive detection, and other applications reach new peaks by employing millimeter-wave techniques.

The development of a complete line of field-tested millimeter wave components by Microwave Associates has made broadly available the very significant advantages of the sub-centimeter region.

Microwave Associates has long pioneered the millimeter region. Available now are reliable magnetrons, complete radar mixer-duplexers, supersensitive silicon diode detectors and many other components for active and passive detection between 30,000 and 70,000 mcs., also circular waveguide components for operation in the low attenuation TE_{01} mode.

Laboratory equipment includes test benches for frequency, power, impedance and attenuation measurements.

SYSTEMS PLANNING

Our Applications Engineering Department is prepared to help you plan all phases of your millimeter wave operations. For direct information, write or call.

SEND FOR DATA

Catalog 58CP describes more than 300 components for the best in millimeter-wave operation . . . gives you complete engineering and application facts. Write for your copy.

MICROWAVE ASSOCIATES, INC.
BURLINGTON, MASSACHUSETTS ● Telephone: BRowning 2-3000

(Continued from page 28A)

received his Ph.D. degree in physics from the same school in 1953. He joined the company as an engineer in the materials engineering department in 1953 and subsequently became a supervising engineer and a section manager in this department. In September, 1955, he was named a section engineering manager in the semiconductor department at Collins Avenue; and in June, 1956, he became an advisory engineer at Youngwood, Pa. and comes to his new assignment from that position.

❖

N. P. Hiestand (S'49–A'50–M'55) is the newly appointed Manager, Product Development of Varian Associates' Instrument Division according to Ralph Kane, vice-president of the electronics firm's Instrument Division.

Since February, 1955, Mr. Hiestand has been Manager, Power Tube Applications Department in Varian's Tube Division. Before that, from 1950 to 1955, he was the division's Manager of Power Tube Development dealing with both high power c-w amplifiers for television and communications service and high power pulsed tubes for radar use. Mr. Hiestand joined Varian Associates in 1950 after participating for two years in research on ceramic windows for high power pulsed klystrons at the Stanford University Microwave Laboratory.

N. P. HIESTAND

Mr. Hiestand was graduated in physics from Pomona College and received a degree in electrical engineering from Stanford University.

❖

L. D. Kovach (A'53) has been appointed Professor of Mathematics and acting head of the Department of Mathematics and Physics at George Pepperdine College in Los Angeles, Calif. Dr. Kovach will retain his position as design specialist at the Douglas Aircraft Company, El Segundo, Calif.

❖

The appointment of **H. K. MacKechnie** (A'48–M'48–SM'54) as technical director of the electronics section of the Lowell Technological Institute Research Foundation was announced recently. Mr. MacKechnie, who assumed his position June 1, will have charge of securing contracts, handling customer relations, and directing project work in electronics, electronic controls for industry, and automation.

He comes to the L.T.I. Research Foundation from Technical Design & Development Co., Inc., where he was head of the Boston Division as engineering manager. Prior to this time Mr. MacKechnie de-

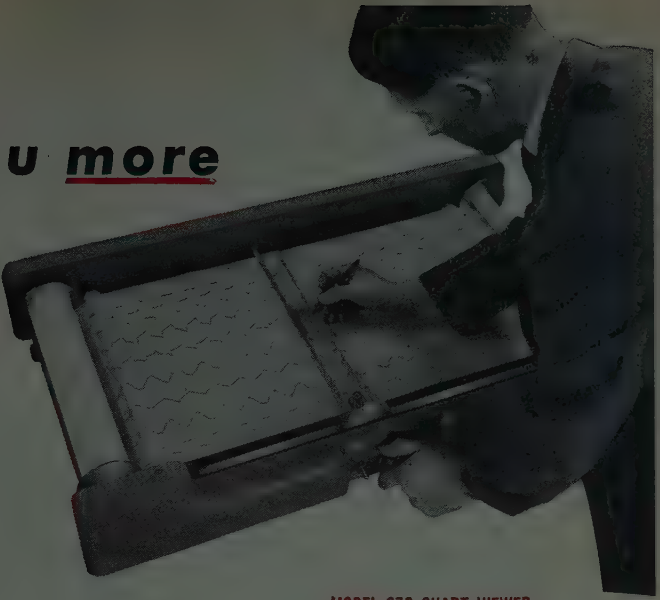
(Continued on page 40A)

...the record tells you *more*

from a

SANBORN SYSTEM

DESIGNED SPECIFICALLY FOR YOUR TYPE OF WORK

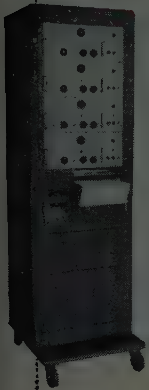


MODEL 276 CHART VIEWER

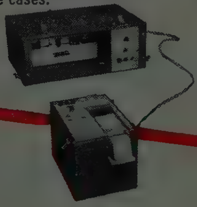
Permits convenient, variable speed editing and study of Sanborn charts and other types up to 16" wide, 200 ft. long. Single control for direction, paper speeds (15" to 100'/min). Transparent cursor slides left or right, adjusts for accurate alignment with coordinates.

1- TO 8-CHANNELS, 12 PLUG-IN PREAMPLIFIERS

150 SERIES



Features of the "150 series" direct writers include: frequency response to 100 cps; linearity 1% overall; inkless recording in true rectangular coordinates by heated stylus on plastic coated Permapaper charts; current feedback driver amplifier and regulated power supply for each channel. Recorder has 9 chart speeds, 0.25 to 100 mm/sec; individual stylus heat controls, time-code marker. Up to 6-channels can be housed in one vertical cabinet. Amplifiers, recorder also available in individual portable cases.



6-, 8-CHANNELS, FLUSH FRONT RECORDER, FREQUENCY RESPONSE TO 120 CPS

350 SERIES

New "350" series direct writers with compact plug-in preamps in modules of up to 4; individual power supplies; current feedback transistorized power amplifiers; limiter circuit ahead of power amplifiers; velocity feedback galvanometer damping; enclosed galvanometers. Linearity 0.2 div. over entire 50 divisions. Recorder-power amplifier-power supply package has 0.1 volt/div. sensitivity, can be used separately; pushbutton controls for 9 chart speeds 0.25 to 100 mm/sec; individual stylus heat controls; contacts for remote control; inkless rectangular coordinate recording on Permapaper charts.

6-, 8-CHANNELS

850 SERIES

Compact "850" series direct writers use 7" high plug-in preamplifiers in modules of up to eight and "350" flush front recorder package with transistorized power amplifiers, power supply; features velocity feedback galvanometer damping; linearity 0.2 div. over entire 50 divisions; 9 chart speeds from 0.25 to 100 mm/sec controlled by electric pushbuttons; inkless recordings on Permapaper charts. Available preamps include Servo Monitor (demodulator) and DC Coupling. Carrier, Chopper Stabilized and Low Level types are in development.

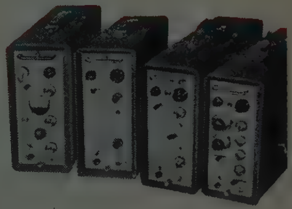
COMPUTER READOUT . . . AUTOMATIC PROGRAMMING

150 SERIES

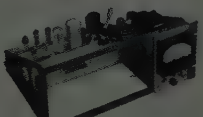
"150 series" 6-, 8-channel consoles in 46½" high mobile cabinet. Dual-Channel Amplifiers have selectable sensitivity from 0.01 to 10 volts/div.; internal calibration 2 volts ±1% freq. response flat to 20 cps. Optional Programmer sequences system operation in 20 steps, including recorder turn-on, calibration, computer DC level reading, recording for pre-set time, turn-off and reset.

SELF-CONTAINED UNIT PREAMPLIFIERS TO DRIVE 'SCOPES, OPTICAL OSCILLOGRAPHS, TAPE RECORDERS, ETC.

Portable "350" series include Carrier, DC Coupling Servo Monitor (demodulator), True Differential DC types; others in development. Mount in portable "450" cases or in four-unit modules in 19" frame. Use individual power supplies. One "450" case and power supply can serve any "350" Preamp.



PORTABLE INDICATORS FOR STRAIN, ETC.



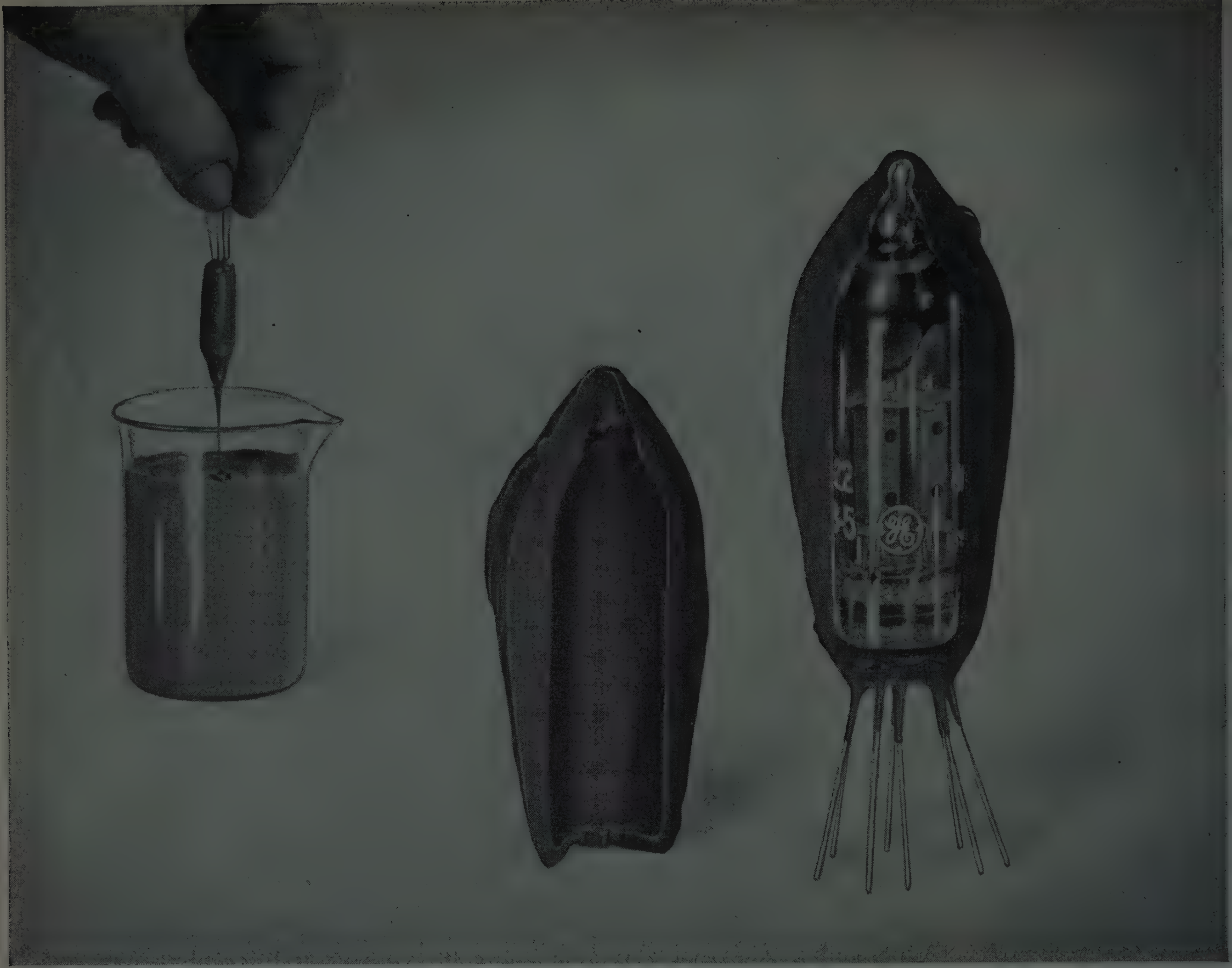
Model 150-300/700 Wide Band Amplifier and Power Supply accepts "150" series preamplifiers — for use with low power galvanometers, oscilloscopes, panel meter. Freq. range DC to 10,000 cps (but limited by particular preamp range). Panel meter has center zero scale, 25 divisions each side of center.

(ALL DATA SUBJECT TO CHANGE WITHOUT NOTICE)

For complete data, call your local Sanborn Engineering Representative or write the Industrial Division in Waltham.

SANBORN COMPANY
Industrial Division
175 Wyman Street, Waltham 54, Mass.

Visit Sanborn Booths 1454-1455 at Wescon Show



G-E RTV is an easily applied potting and encapsulating material. Tough, heat-resistant, resilient, it does not shrink or form voids during cure.

New RTV silicone rubber from G.E.

CURES WITHOUT HEAT • LOW VISCOSITY • SOLVENT-FREE • NO VOIDS OR SHRINKAGE

CURES WITHOUT HEAT G.E.'s RTV (room temperature vulcanizing) silicone rubber cures at room temperature in any time you select up to 48 hours. It comes in a wider viscosity range than any similar compound—from 250 poises (pourable) to 15,000 poises (spreadable). Easily applied by pouring, dipping, spreading or with a pressure gun.

WON'T SHRINK, VOID-FREE RTV compounds are 100% solids (no solvents). They cure without shrinkage; form no voids; provide resilient, shock-absorbent protection against physical damage or moist and corrosive atmospheres. Tensile and tear strength exceed those of previously available materials and are retained after prolonged heat aging.

RESISTS HEAT ABOVE 300°C General Electric RTV silicone rubber keeps its high dielectric strength at temperatures above 300°C. It has the well-known properties of silicone rubber, such as ability to withstand moisture, weathering, ozone, corona, oxidation and exposure to fuels and solvents.

IDEAL FOR POTTING AND ENCAPSULATING General Electric RTV compounds flow easily into and around complex shapes. They are ideal for potting and encapsulating. Other uses include caulking and sealing in hard-to-reach places, performing "on-the-spot" rubber repairs, model making and molding in low-cost plastic tooling.

Send for complete application data. If you'd like a sample for evaluation, drop us a note telling us about your proposed application.

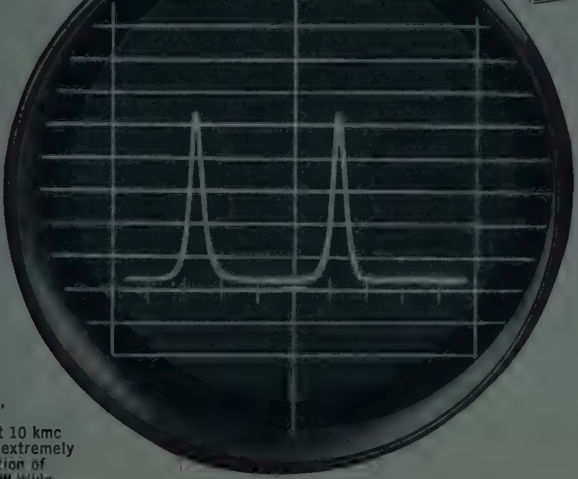
OPERATION up turn GENERAL ELECTRIC

GENERAL ELECTRIC

Silicone Products Dept.   Waterford, N. Y.

Visual display instantly shows distribution of microwave energy around carrier frequency. **Model TSA** Spectrum Analyzer.

Pulsed signal displayed as a function of time. **Model TSA-S** Combination Synchroscope-Spectrum Analyzer.



Rapid signal comparison, accurate to .00025% at 10 kmc because of extremely fine resolution of **Model TSA-W** Wide Dispersion Spectrum Analyzer.

Direct, immediate observation of spurious transmitter radiation. **Model SA-84** Multi-Band Spectrum Analyzer.

VISUAL MICROWAVE ANALYSIS

4 microwave analyzers cover every application, 10–44,000 mc

MODEL TSA SPECTRUM ANALYZER—25 kc resolution, 400 kc to 25 mc dispersion. 5 sensitive tuning units.

MODEL TSA-S COMBINATION SYNCHROSCOPE-SPECTRUM ANALYZER—5 kc to 5 mc adjustable bandwidth, 400 kc to 25 mc dispersion. Time and frequency display. 5 sensitive tuning units.

MODEL TSA-W VERY WIDE DISPERSION SPECTRUM ANALYZER—7 kc and 50 kc resolution, 100 kc to 70 mc dispersion. Logarithmic amplitude display. 5 sensitive tuning units.

MODEL SA-84 MULTI-BAND SPECTRUM ANALYZER—10 to 40,880 mc in a single unit.

Polarad spectrum analyzers are basic "scopes" for all microwave work. They display instantaneously such parameters as attenuation, insertion loss and gain, bandwidth characteristics, SWR, frequency, power, etc. In addition they detect and display modulator and transmitter malfunctions such as double moding, misfiring, pushing and pulling by a magnetron, and frequency drift.

FREE LIFETIME SERVICE ON ALL POLARAD INSTRUMENTS

MAIL THIS CARD for specifications. Ask your nearest Polarad representative (in the Yellow Pages) for a copy of "Notes on Microwave Measurements"

POLARAD ELECTRONICS CORPORATION

43-20 34th Street, Long Island City 1, N.Y.

POLARAD ELECTRONICS CORPORATION:

Please send me information on

☐ Microwave Spectrum Analyzers

☐ Model R Receiver (see reverse side of this page)

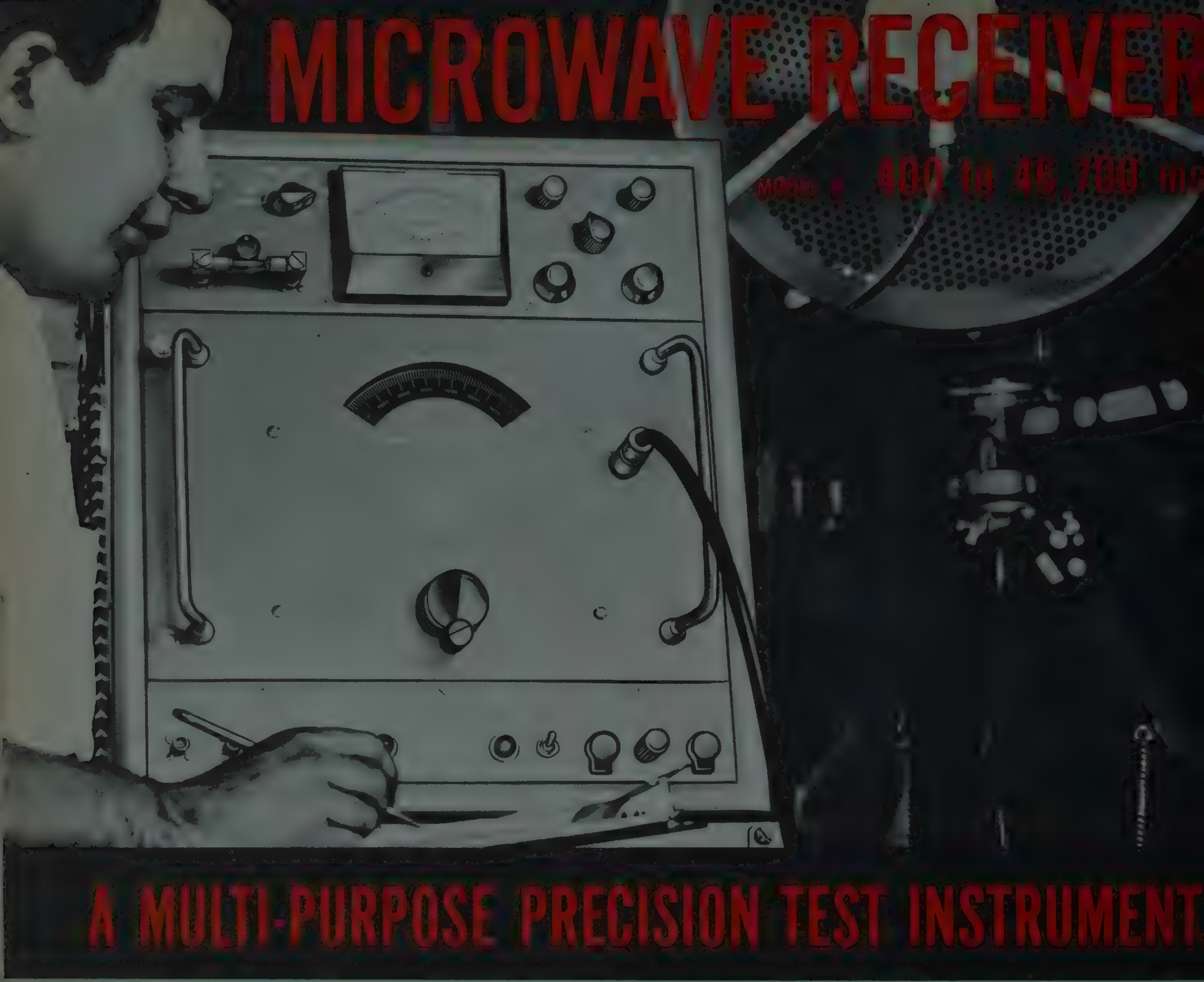
My application is:__________

Name__________

Title__________Dept.__________

Company__________

Address__________



DETECTS AND MEASURES:

- Antenna patterns
- Field intensity
- R-F power
- R-F noise figure
- Leakage and interference
- Filter characteristics
- Bandwidth of microwave cavities
- Attenuation
- Insertion gain and loss
- Relative power differences between fundamental signal and harmonics

POLARAD

MAIL THIS CARD for specifications. Ask your nearest Polarad representative (in the Yellow Pages) for a copy of "Notes on Microwave Measurements"

Now — one basic instrument serves for general communications as well as for detection and complete quantitative analysis of microwave energy.

Polarad Model R Receiver accepts all microwave signals: AM, FM, CW, MCW and pulse. Power and frequency are read directly on front panel indicators.

It permits all standard forms of signal monitoring: special output jacks for audio and video; trigger output to reproduce pulse width and repetition rate; recorder output to transcribe signals through commercial recording equipment.

Model R is simple to operate, extremely sensitive, highly accurate, and is designed for quick, easy inspection and servicing. It provides AFC, AGC, and continuous UNI-DIAL tuning. Eight interchangeable tuning units cover the entire frequency range.

Postage Will be Paid by Addressee

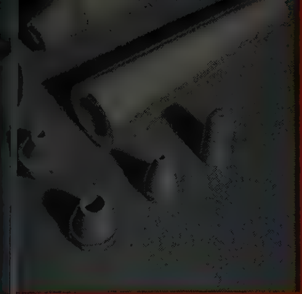
No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD
First Class Permit No. 18, Long Island City 1, N.Y.

POLARAD ELECTRONICS CORP
43-20 34th St., Long Island City 1, N.Y.

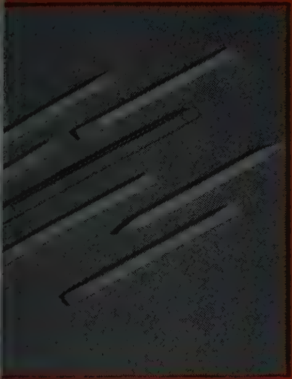
POLARAD ELECTRONICS CORPORATION
43-20 34th Street Long Island City 1, N.Y.
Representatives in principal cities

FREE LIFETIME SERVICE ON ALL POLARAD INSTRUMENTS



Abrasion Resistant

Blast Nozzles. Spray Nozzles. homogeneous, long-lived. Suited most exacting uses.

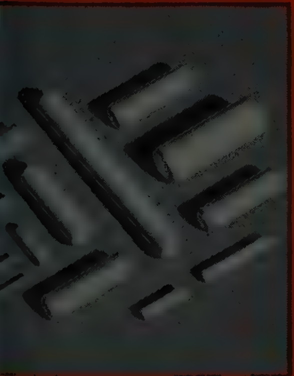


Non-Inductive

nent Tool Blades. Non-metallic, ensitive machine and instrument gs—other demanding applications.

Thin . . . Strong

on Tube Spacers as thin as .009″ remarkable strength. Similar parts solve other application problems superior insulation is needed.



Precision Finishes

th, easily coated AlSiMag Cores nk, Metal Film and Carbon De- ed Resistors.

ALSIMAG®

DATA FOR DESIGNERS

NEW!

AlSiMag Alumina Ceramics open new fields for designers . . . permit designing to higher temperatures, higher frequencies, greater strengths.

Designers are generally familiar with the plus values of AlSiMag technical ceramics for standard industry applications. However, recent developments—particularly in new, high-strength, high-temperature AlSiMag Aluminas—have greatly enlarged their range of usefulness.

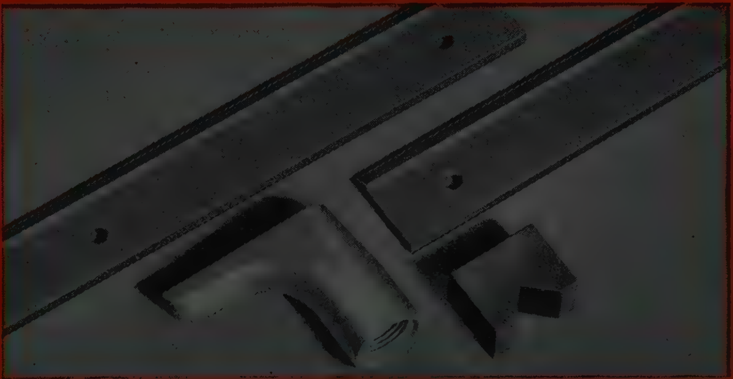
Do you need a material with such versatile characteristics as shown on this page? AlSimag technical ceramics have helped many designers solve problems . . . may help solve yours. Send blueprint with complete operating details for our recommendations.

Visit our Booths Nos. 606-607 at WESCON

AMERICAN LAVA CORPORATION
CHATTANOOGA 5, TENN.
57TH YEAR OF CERAMIC LEADERSHIP

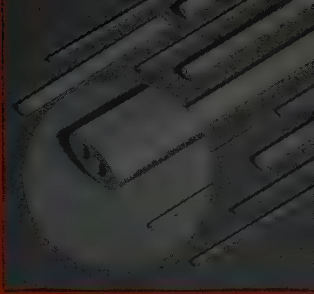
A subsidiary of
Minnesota Mining and
Manufacturing Company

For service, contact Minnesota Mining & Manufacturing Co. Offices in these cities (see your local telephone directory): Atlanta, Ga. • Boston: Newton Center, Mass. • Buffalo, N. Y. • Chicago, Ill. • Cincinnati, O. • Cleveland, O. • Dallas, Texas • Detroit, Mich. • High Point, N. C. • Los Angeles, Calif. • New York: Ridgefield, N. J. • Philadelphia, Pa. • Pittsburgh, Pa. • St. Louis, Mo. • St. Paul, Minn. • So. San Francisco, Calif. • Seattle, Wash. • Canada: Minnesota Mining & Manufacturing of Canada, Ltd., P. O. Box 757, London, Ont. All other export: Minnesota Mining & Manufacturing Co., International Division, 99 Park Ave., New York, N.Y.



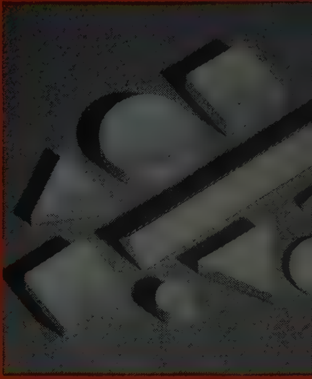
Heat Resistant

Support Rings for Heat Treating Fixtures. Welding Jigs. Hold-down Jigs for heat applications.



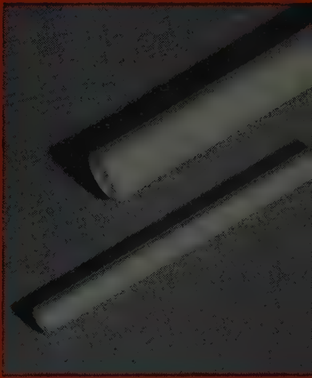
Precision Tolerances

Minute, yet strong tubing of AlSi Alumina. Parts in inset magnified th times (smaller one .013″ OD); ot approximate actual size.



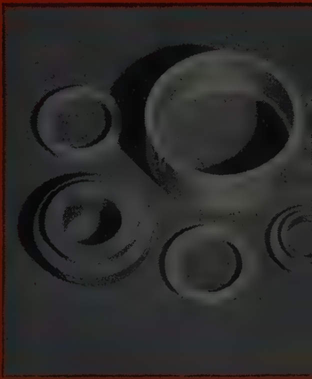
Hard

AlSiMag Tool Tips for cutting machining strongest alloy steels.



Durable

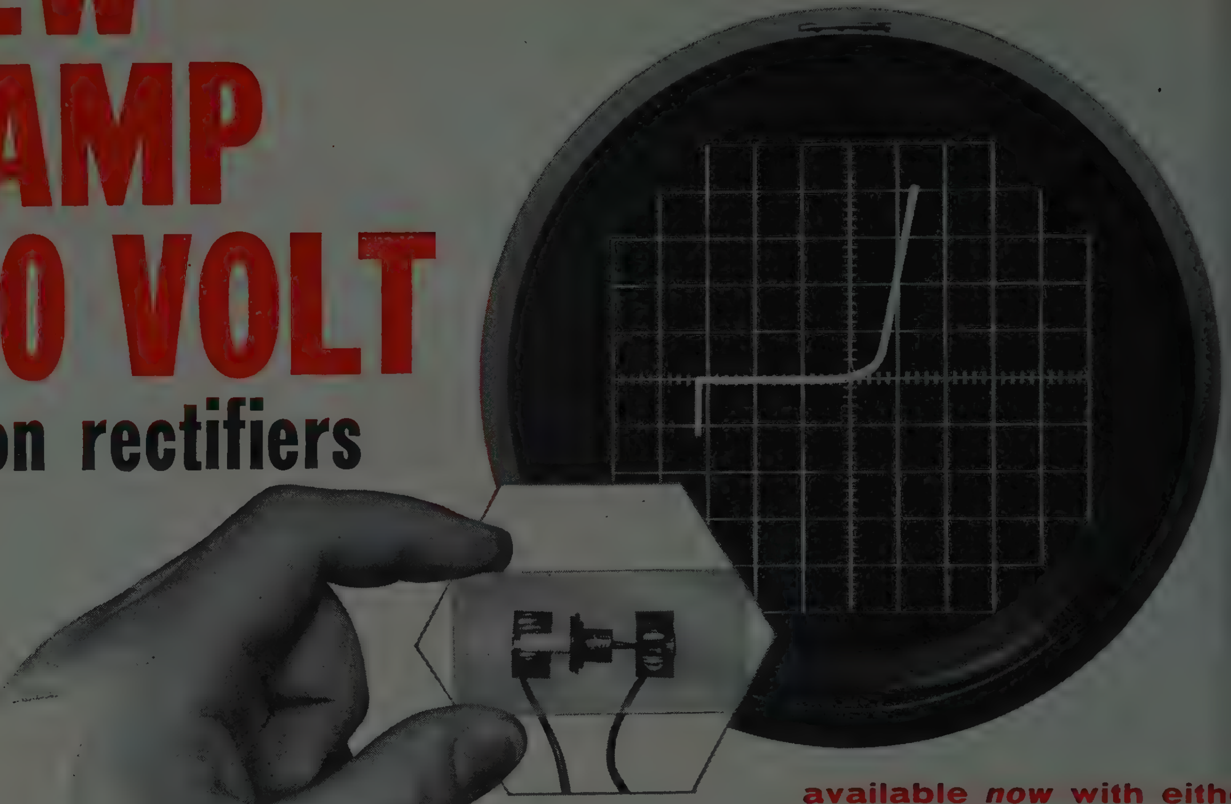
Rollers for flattening inductance wi a new application for AlSiMag.



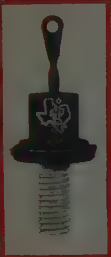
Acid Resistant

Rotary Seals and Plungers. Extrac nary wearing qualities. Surface fini to most exacting specifications.

NEW 3 AMP 600 VOLT T/I diffused junction silicon rectifiers



available *now* with eithe
anode or cathode to stu

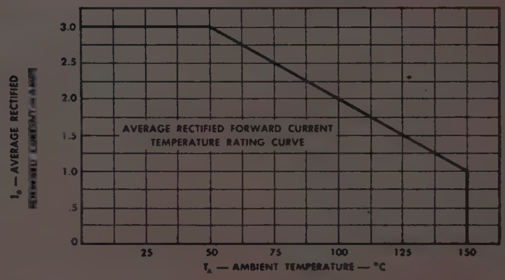


(ACTUAL SIZE)

TI diffused junction silicon rectifiers give you full 3-ampere output at 50°C with PIV ratings to 600 volts.

The TI diffusion process assures you of complete uniformity of characteristics and provides either anode-to-stud or cathode-to-stud polarity. Quick easy wiring into production assemblies is additionally facilitated by the eyelet on the top lead. All welded, rugged construction with glass-to-metal seal provides high resistance to shock and vibration.

Check the characteristics below and specify economically priced TI rectifiers for all your medium power applications.



Anode-to-stud units denoted by "R" suffix to type number.

maximum ratings	1N1124 1N1124R	1N1125 1N1125R	1N1126 1N1126R	1N1127 1N1127R	1N1128 1N1128R	unit
Peak Inverse Voltage at —65°C to +150°C	200	300	400	500	600	V
*Average Rectified Forward Current at +50°C	3	3	3	3	3	Amp
*Average Rectified Forward Current at +150°C	1	1	1	1	1	Amp
*Recurrent Peak Forward Current at +50°C	10	10	10	10	10	Amp
Surge Current, 1 Cycle at 60 Cycles at +50°C	25	25	25	25	25	Amp
Operating Temperature, Ambient	—65 to +150					°C
specifications						
Max. Full Cycle Avg. Reverse Current at +150°C	0.3	0.3	0.3	0.3	0.3	mA
Max. Reverse Current at PIV at +25°C	10	10	10	10	10	µA
Max. Forward Voltage Drop at I_b = 1 Amp at +25°C+	1.1	1.1	1.1	1.1	1.1	V

* Rectifier mounted on 2″ x 2″ Heat Sink, 1/16″ aluminum.

also immediately available in production quantities

TI 1500 VOLT RECTIFIERS

Single junction reliability assures the high reliability your circuits require.

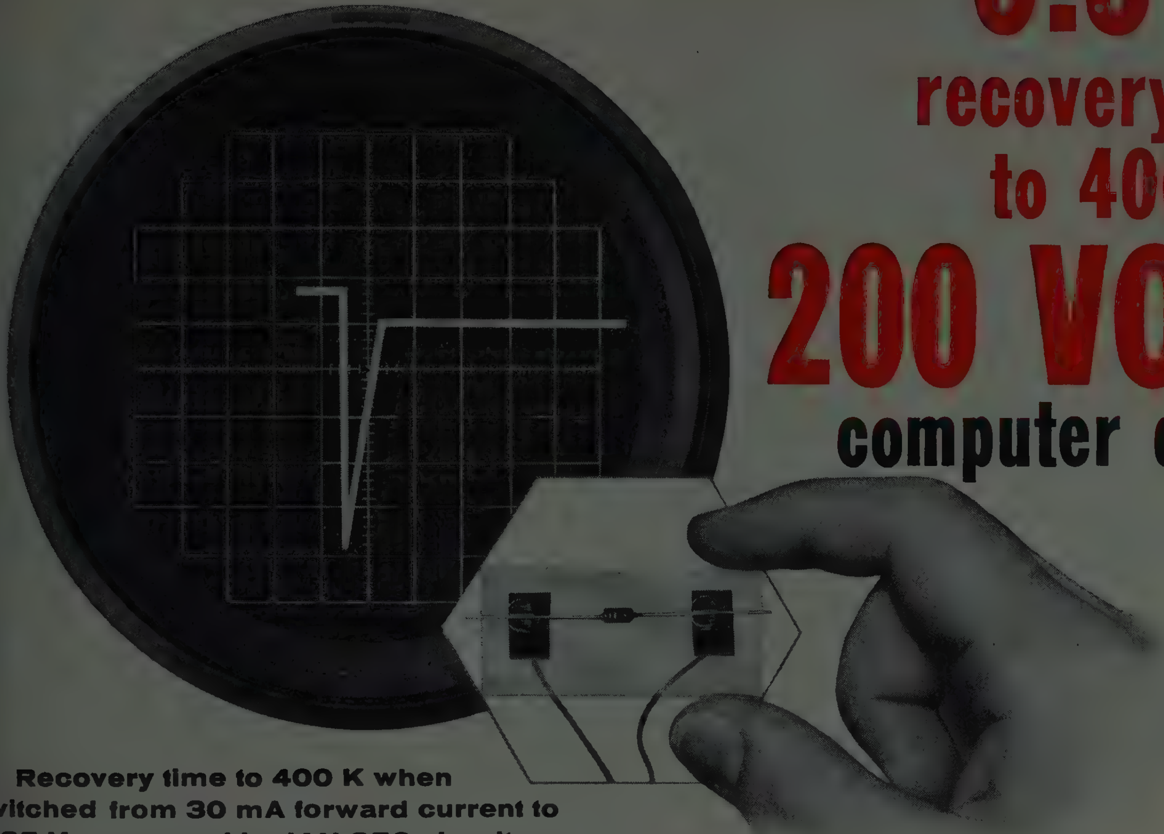
	Peak Inv Voltage V	Ave Rect Fwd Current mA	Recurrent Peak Current
1N1130*	1500	300	1A
1N1131†	1500	300	1A
1N588	1500	25	150 mA
1N589	1500	50	250 mA

* cathode-to-stud † anode-to-stud

TEXAS INSTRUMENTS
INCORPORATED
SEMICONDUCTOR - COMPONENTS DIVISION
POST OFFICE BOX 312 • DALLAS, TEXAS

Contact your nearest TI sales office or distribut
for detailed silicon diode and rectifier data shee

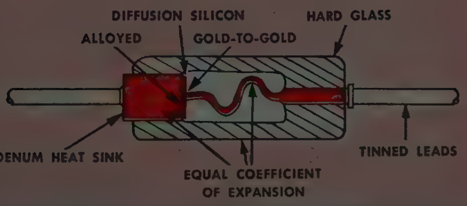
T/I diffused silicon 0.3 µ sec recovery time to 400 k 200 VOLT computer diodes



Recovery time to 400 K when
witched from 30 mA forward current to
-35 V measured in JAN 256 circuit.

(ACTUAL SIZE)

cutaway view of TI glass diode



TI diffused silicon computer diodes give you 0.3 µ sec maximum recovery time at 400 K with PIV ratings to 200 volts.

For your computer applications, TI hard glass diodes provide 100 mA average rectified forward current at 25°C. All units are rated to meet military requirements, and provide fast recovery, higher conductance ratings, and shock-proof reliability.

Check the characteristics below and specify TI diodes for all your computer applications.

Also in this same glass package, TI general purpose diodes

max ratings	1N645	1N646	1N647	1N648	1N649	
PIV	225	300	400	500	600	V
I_O	400	400	400	400	400	mA
I_O	150	150	150	150	150	mA
i_l	1.25	1.25	1.25	1.25	1.25	amp
P	600	600	600	600	600	mW
I_{DC}	3	3	3	3	3	Amp
T_A	−65 to +150					°C
specifications						
V_Z	275	360	480	600	720	V
LI_b	0.2	0.2	0.2	0.2	0.2	µA
LI_b	15	15	20	20	25	µA
E_b	1.0	1.0	1.0	1.0	1.0	V
C	9	9	9	9	9	µµf

maximum ratings	1N659	1N660	1N661	
Peak Inverse Voltage at −65 to +150°C	50	100	200	V
Average Rectified Forward Current at +25°C	100	100	100	mA
Average Rectified Forward Current at +150°C	30	30	30	mA
Recurrent Peak Forward Current at +25°C	320	320	320	mA
Operating Temperature, Ambient	−65 to +150			°C
Altitude	100,000			ft
specifications				
Minimum Breakdown Voltage at +100°C	60	120	240	V
Maximum Reverse Current at PIV at +25°C	5	5	10	µA
Maximum Reverse Current at PIV at +100°C	25	50	100	µA
Maximum Voltage Drop at I_O = 6mA at 25°C	1	1	1	V
Maximum Reverse Recovery Time*	0.3	0.3	0.3	µsec
Typical Capacitance at −10V at 1 mc	2.7	2.7	2.7	µµfd

Recovery time to 400K when switched from 30 mA forward current to −35V. Measurement made with a Hauman ND-1 standard pulse recovery test set approved by JETEC-14 and described in JAN-256.

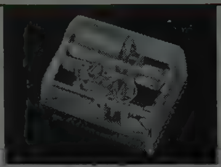
XAS INSTRUMENTS SALES OFFICES
LAS • NEW YORK • CHICAGO • LOS ANGELES
CAMDEN • DAYTON • DENVER
POIT • OTTAWA • SYRACUSE • SAN DIEGO
WALTHAM • WASHINGTON D. C.

TEXAS INSTRUMENTS
INCORPORATED
SEMICONDUCTOR - COMPONENTS DIVISION
POST OFFICE BOX 312 • DALLAS, TEXAS

LOOKING
FOR THE
SENSITIVE TYPE?

TRY
THIS
NUMBER SV-1C/5000D

The Advance type SV Sensitive Relay (shown at right) is $1\frac{9}{16}''$ high x $2\frac{5}{8}''$ long x $2\frac{1}{16}''$ wide. Also available is the type SO Miniature Sensitive Type, $1\frac{7}{32}''$ high x $1\frac{1}{4}''$ long x $1\frac{1}{8}''$ wide.



SPECIFICATIONS

Coil resistance: From .005 Ohms at .005 volts DC to 40,000 Ohms at 14.0 volts DC.

Nominal power required: Factory adjusted at .005 watts.

Contact rating: 1 amp resistive, .5 amps inductive at 115 volts AC or 26.5 volts DC.

Contact arrangement: SPDT only.

Advance type SV relays are ultra-sensitive, yet durable—dust-tight, yet fully adjustable. Contacts and all working parts are protected by a transparent molded plastic cover.

Sensitivity can be adjusted from the 5-milliwatt factory setting by turning the vernier screws. Use the type SV in any DC circuit where power consumption is limited to a few thousandths of a watt.

Available from leading distributors

WRITE FOR COMPLETE DETAILS
Data sheets on the SV Sensitive Relay and the SO Miniature Sensitive Relay will be sent promptly.

ADVANCE RELAYS
ELGIN A PRODUCT OF ELECTRONICS DIVISION
ELGIN NATIONAL WATCH COMPANY
Dept. D, 2435 N. Naomi St., Burbank, California

(Continued from page 34A)

voted his efforts to engineering supervision and management, doing consulting and project work for such companies as American Machine & Foundry Co., and Barkley & Dexter, Inc. He is a registered professional engineer in Massachusetts and Ohio.

A 1933 graduate of M.I.T. with a degree of S.B. in electrical engineering and electronics, Mr. MacKechnie has spent more than twenty years in design and development engineering. Following graduate study at the Harvard Engineering School and in the New York University Graduate School of Business Administration, he was resident manager in Cincinnati for the Mutual Boiler Insurance Co. in charge of sales, underwriting, engineering and inspection. He then became senior engineer for the National Board and specialized in electronic controls. This led to four years as project engineer on military electronic equipment at Harvard Radio Research Laboratories and Raytheon Manufacturing Co., and two years as laboratory chief of the Countermeasures Laboratory at Cambridge Research Center with membership in the Aircraft Radio and Electronic Committee, Department of Defense.

Mr. MacKechnie is a member of the Boston chapter of the Professional Groups on Engineering Management and Audio. He has been affiliated with the New England Society of Professional Engineers and the A.I.E.E. He holds the second oldest amateur radio operator's license in New England, having had the call letters W1ADP since 1922.

❖

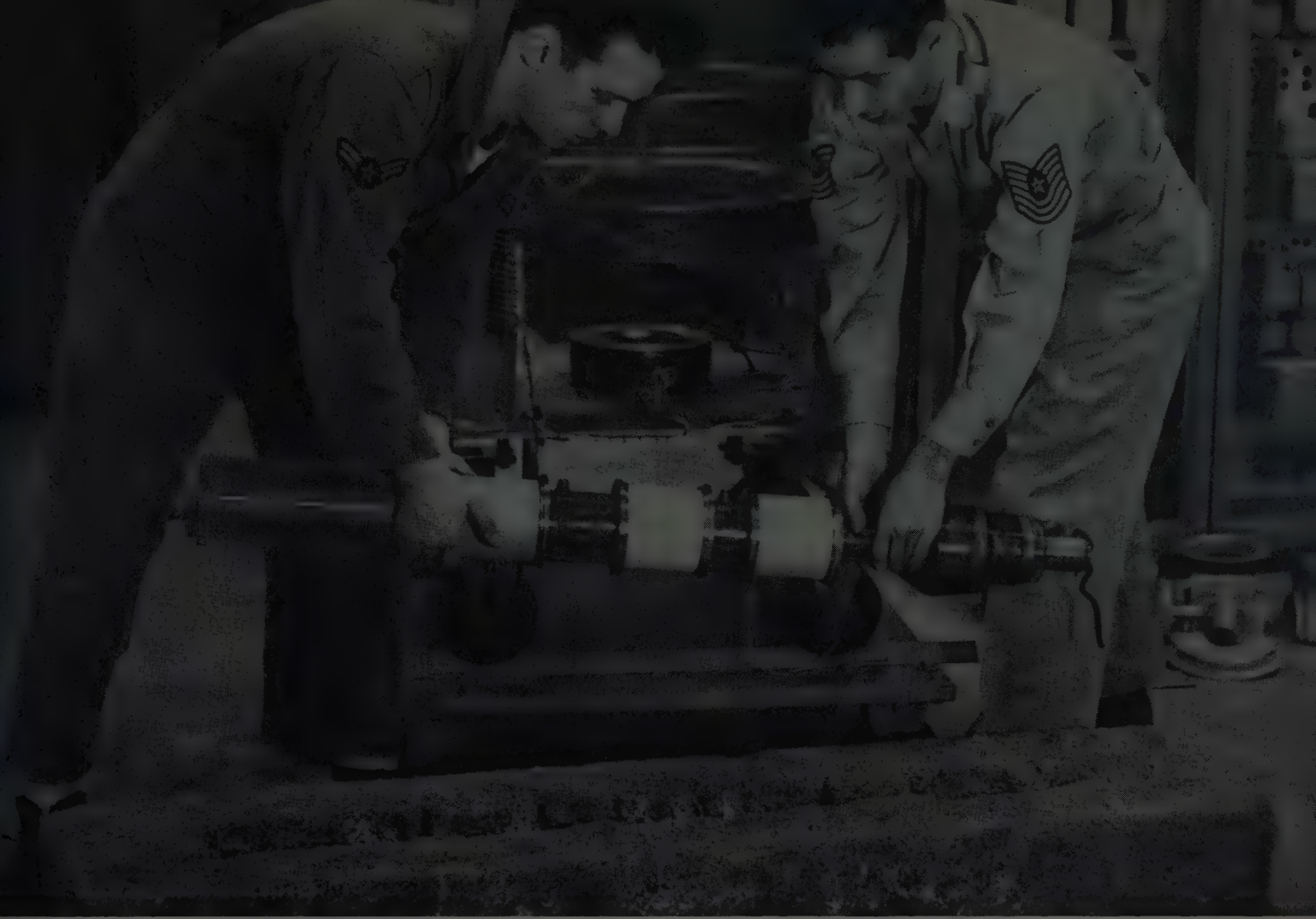
The appointment of **J. D. Mayfield** (A'50) as Sales Engineer was announced by the Electronic Engineering Company of California.

J. D. MAYFIELD

Mr. Mayfield was formerly a Senior Engineer in the Engineering Department of the company and was Project Engineer on a classified project for Air Technical Intelligence Command. Other projects on which he has worked include design, testing and installation of an automatic timing, firing, and camera control system for Naval Ordnance Test Station and the design and testing of a gyro trouble-shooting test set for Hughes Aircraft Co.

He has been employed by the Electronic Engineering Company as an engineer since 1955. Before joining EECo he was a staff member and engineer for the Sandia Corp., Albuquerque, N. M., from 1951 to 1955 where he was engaged in the design, development and field testing of electronic systems for nuclear weapons.

(Continued on page 42A)



U. S. Air Force personnel remove 25,137 hour klystron from advanced Pole Vault base. Department of Defense Photograph.

Eimac Klystrons Going Strong

after 25,000 Hours in Pole Vault Tropo-Scatter Service

After 25,137 hours on the air, and still in perfect operating condition, this Eimac 3K50,000LF UHF klystron has been acquired through the cooperation of the U.S. Air Force and Canadian Marconi, Ltd. This klystron was one of the original tubes installed in Project Pole Vault, the first tropo-scatter communications line ever established. The tube is just one of a number of Eimac klystrons that have exceeded 25,000 hours of reliable on-the-air time in this system. Eimac klystrons are used as final amplifiers in the Pole Vault 10 kilowatt transmitters that handle multiple-channel voice and teletype communications. Experience with this first system in our early warning defense network confirmed klystron-powered tropospheric scatter as an outstandingly dependable system of long distance communication.

The exceptional performance of these tubes under the difficult logistical and environmental conditions of the far north is indicative of the reliability and conservative rating of performance-proved Eimac external-cavity klystrons. Eimac amplifier klystrons are now being used extensively for tropo-scatter communications throughout the United States, Canada and other regions of the world. Eimac klystrons for communications and pulse applications are now available covering frequencies from VHF to SHF and to multi-megawatt output powers.

For further information, write for a copy of the 24-page booklet "Klystron Facts Case Five."

EITEL-McCULLOUGH, INC.
SAN BRUNO · CALIFORNIA
Eimac First **for reliable tropo-scatter klystrons**

Eimac®

Products Designed and Manufactured by Eimac

- Negative Grid Tubes
- Reflex and Amplifier Klystrons
- Ceramic Receiving Tubes
- Vacuum Tube Accessories
- Vacuum Switches
- Vacuum Pumps

Make Your Reservations Now - - Plan to attend the Fourth - -

Conference On Communications

SPACE FRONTIERS IN ENGINEERING AND EDUCATION

Sponsored by the Cedar Rapids Section

CEDAR RAPIDS, IOWA
Sheraton-Montrose Hotel
SEPTEMBER 12-13

Address:
"Conference on Communications"
P. O. Box 948
CEDAR RAPIDS
IOWA

Exhibits : Speakers : Banquet : Tours

For Information on Registration and Housing
Contact: RICHARD BURTON

Ceramaseal HERMETIC TERMINALS

- 100% leak-tested
- High alumina ceramic
- Installation by brazing, soldering, or welding
- High resistance to thermal shock
- Pressures to 10,000 psi

SPECIAL TERMINALS, SAPPHIRE-TO-METAL SEALS AND MAGNETRON WELLS AVAILABLE

High alumina ceramic and metal parts are brazed together to form a high-strength, long-life, molecular seal.

Stock sizes for up to 100 KV-DC operating voltages available for short delivery.

For complete information, brochure, spec sheets and price lists, write or phone: Ceramaseal, Inc., New Lebanon Center, N. Y. West Lebanon 3-5851.

CERAMASEAL, Inc.

IRE People

(Continued from page 40A)

From 1950 to 1951 he was employed by Collins Radio Co. in the development and testing of UHF communications and missile guidance radio link.

He received his B.S. degree in electrical engineering from Oklahoma State University (Oklahoma A and M) in 1950.

❖

Satellite-Kennedy, Inc. of California has been established as the research and development affiliate of D. S. Kennedy & Co., Cohasset, Mass. The parent concern has, since its organization in 1945, been active in the design and production of giant antennas for electronic systems applications, such as radar; scatter communications; aircraft, missile, and satellite tracking and guidance; and radio astronomy.

The new group, presently located in offices at 4109 El Camino Way, Palo Alto, Calif., will be concerned with research and development advancing the science of electromagnetic propagation and control.

F. W. Morris, Jr., (M'49–SM'52) who has been vice-president and director during the formation of the California company, will return to his independent practice as an electronic engineering and management consultant. Mr. Morris will continue as a consultant with Satellite-Kennedy.

Mr. Morris has formerly been active with San Francisco Bay Area organizations including Sylvania Electric Products Inc., Remler Company, Bomac Laboratories, Inc., and Instruments For Industry, Inc. He has also served as an advisor with the Department of Defense and the Massachusetts Institute of Technology.

Mr. Morris is a graduate of the California Institute of Technology, and a registered professional electrical engineer of the State of California.

❖

James Spool

The appointment of **James Spool** (M'56) as marketing manager of Dynacor, Inc. has been announced by Sprague Electric Company's subsidiary which manufactures magnetic bobbin and tape cores for computers and magnetic amplifiers at Kensington, Md.

Mr. Spool was formerly a member of the Washington field engineering staff of the Sprague Electric Company. Previously, he had served with the Research and Development Division of the U. S. Army Office of the Chief of Ordnance in Washington. A graduate in electrical engineering from the Cooper Union in New York City, Mr. Spool received his LL.B.

(Continued on page 46A)

A NEW BRAND IN THE WEST

SEE THESE PRODUCTS AND SERVICES OF TELECOMPUTING CORPORATION AT WESCON BOOTHS NO. 1718-19:

WC

WHITTAKER CONTROLS—*advanced fuel control, hydraulic and pneumatic valves for aircraft and industrial uses.*

WG

WHITTAKER GYRO—*rate, floated rate, and free gyros, including the new spring driven gyro.*

BE

BRUBAKER ELECTRONICS—*get the story on the nation's leader in IFF and related equipments.*

DI

DATA INSTRUMENTS—*high-precision data reduction equipment for large film and glass plates for applications in photogrammetry, astronomy, and flight tests.*

NI

NUCLEAR INSTRUMENTS—*electronic test device for checkout and monitoring of nuclear weapons control systems.*

ES

ENGINEERING SERVICES—*learn about our complete facility for reduction of missile flight test data.*

TELECOMPUTING CORPORATION

915 North Citrus Avenue, Los Angeles, California

See, and get the facts on these products offered by Telco Electronic Sales Division: capacitors, microminiature relays, delay lines, switches, solenoids, and a complete family of magnetic amplifiers.

Specifically, look for Telco's new high temperature subminiature ceramic capacitor . . . operating temperature –55 C to +155 C . . . variation in capacity only ±10% over entire temperature range . . . voltage rating 200 WVDC . . . these rugged, reliable capacitors, product of a brand new Telecomputing facility, serve a critical need in the electronics industry.

See Neuron, the high speed electromechanical counter at WESCON Booth No. 752.

new from SIE

output meter and calibrated attenuator on front panel

portable · tiltable · rackable

RANGE: 2 cps — 200 kcps
ACCURACY: 2%
OUTPUT: 1 volt
DISTORTION: less than 1%

N-1 signal generator

Another in the line of SIE **Advanced Design Instruments,** human engineered for operating efficiency. Easier to set up • Easier to read • Adjustable viewing angle • Parallax free vernier tuning • Large, easily set control knobs • Protected front panel • Convenient carrying handle.

BENCH OR RACK MODEL **275⁰⁰** f.o.b. Houston, Tex

SIE — ONE OF THE DRESSER INDUSTRIES

SOUTHWESTERN INDUSTRIAL ELECTRONICS COMPANY
2831 Post Oak Road • P. O. Box 13058 • Houston 19, Texas

SAGE

"Silicohm" POWER RESISTORS

NOW AVAILABLE IN 10 STANDARD SIZES

TYPE "S" AXIAL LEAD RESISTORS

	Length	Diam.	Resistance
SS2W	1/2"	X 1/4"	to 1300 ohms.
S2W	5/8"	X 1/4"	to 5000 "
S3W	3/4"	X 1/4"	to 8500 "
SS5W	7/8"	X 5/16"	to 12000 "
SR5W	1"	X 5/16"	to 16000 "
SL5W	1 1/8"	X 5/16"	to 22500 "
SS7W	1 1/4"	X 5/16"	to 28000 "
S7W	1 3/8"	X 5/16"	to 32000 "
SS10W	1 13/16"	X 3/8"	to 53000 "
S10W	1 15/16"	X 3/8"	to 60000 "

to meet your ever more critical space, resistance, or power requirements.

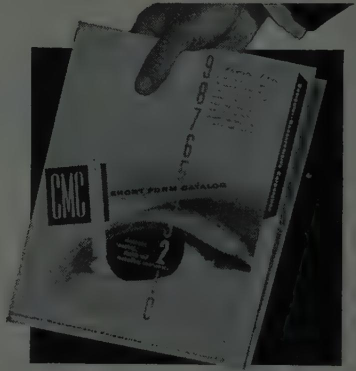
SAGE "SILICOHM" TYPE "S" RESISTORS are designed to meet the electrical and environmental requirements of MIL-R-26C, Characteristic G, including Styles RW57, RW58 and RW59 (*INSULATED*).

Add these features at moderate cost:

PRECISION (to .05% tolerance)
LOW TEMPERATURE COEFFICIENT (20 ppm/°C)

When you buy from....

SAGE ELECTRONICS CORPORATION
300 North Goodman St., Rochester 7, N. Y.



NOW Available...

Computer-Measurements' SHORT FORM CATALOG

Containing Condensed Information on:

- Frequency and Period Counters
- Decade Counting Units
- Preset Decade Counting Units
- Frequency Deviation Meters
- Time-Function Translators
- Digital Printers
- Preset Controllers
- Totalizing Counters
- Time Interval Meters
- Universal Counter-Timers

write for your copy today

Computer-Measurements Corporation
5528 Vineland, Dept. 438 North Hollywood, Calif.

CMC

BEYOND ACCEPTED STANDARDS OF TUBE RELIABILITY. 50,000 high-reliability tubes at a time—a half million a month—receive a special burn-in at General Electric's 5-Star factory. Tube performance is stabilized. Early-life inoperatives are weeded out. Every G-E 5-Star Tube also has passed rigid mechanical and electrical tests before shipment.

OPERATION up turn
Buy now for extra values
GENERAL ELECTRIC

BE SURE YOU GET STABILIZED TUBES WHEN YOU PAY FOR HIGH RELIABILITY!

Only General Electric stabilizes all high-reliability tubes by factory burn-in. What does this 5-Star process mean to you, a manufacturer of electronic equipment with critical sockets?

It's extra protection against production-line shutdowns in your plant, because stabilizing helps weed out any early-life tube inoperatives. Likewise, it's a special safeguard that your radar, communication, or other equipment will prove dependable from the start, when placed in service.

Stabilizing also promotes more uniform tube performance . . . your designers can count on 5-Star Tubes meeting rated requirements at all times. This helps assure that your equipment will continue to perform reliably—building a solid reputation that will lead to repeat orders for new equipment.

When you specify high-reliability tubes, be sure you get the superior quality that only General Electric *stabilized* 5-Star tubes offer! Any G-E Receiving Tube Department office listed below will be glad to supply further information. Phone today!

EASTERN REGION
200 Main Ave., Clifton, N. J.
Phones:
(Clifton) GRegory 3-6387
(N.Y.C.) WI. 7-4065, 6, 7, 8

CENTRAL REGION
3800 N. Milwaukee Ave.
Chicago 41, Illinois
Phone: SPring 7-1600

WESTERN REGION
11840 W. Olympic Blvd.
Los Angeles 64, Cal.
Phones: GRanite 9-7765
BRadshaw 2-8566

Progress Is Our Most Important Product

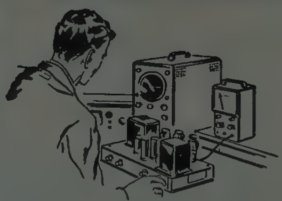
GENERAL ELECTRIC

12-11-204

look what $24.50 buys in test equipment!

HEATHKITS GIVE YOU TWICE AS MUCH equipment for every dollar invested

The famous model V-7A Vacuum-Tube-Voltmeter is a perfect example of the high-quality instruments available from Heath at ½ the price you would expect to pay! Complete, only $24.50



Get the most out of your test equipment budget by utilizing HEATHKIT instruments in your laboratory or on your production line. Get high quality equipment, without paying the usual premium price, by dealing directly with the manufacturer, and by letting engineers or technicians assemble Heathkits between rush periods. Comprehensive instructions insure minimum construction time. You'll get more equipment for the same investment, and be able to fill your needs by choosing from the more than 100 different electronic kits by Heath. These are the most popular "do-it-yourself" kits in the world, so why not investigate their possibilities in your particular area of activity! Write for the free Heathkit catalog now!

Contains detailed descriptions of Heathkit models available, including VTVM's, scopes, generators, testers, bridges, power supplies, etc.

FREE catalog
Mail coupon below for your copy—Now!

Also describes Heathkit ham gear and hi-fi equipment in kit form. 100 interesting and profitable "do-it-yourself" projects!

HEATH COMPANY
A SUBSIDIARY OF DAYSTROM, INC.
BENTON HARBOR 4, MICHIGAN

Name ____________________

Address ____________________

City & Zone ____________________

State ____________________

IRE People

(Continued from page 42A)

degree from George Washington University and was admitted to the District of Columbia Bar in 1955. He received the degree of LL.M. from George Washington in June, 1957.

❖

R. R. Warnecke (SM'48–F'50), director of the electronics and atomistics research department, Compagnie Generale de Telegraphie sans Fil, Paris, was awarded the honorary degree of Doctor of Engineering by the Polytechnic Institute of Brooklyn.

The presentation of the degree was made at the Institute's recent 103rd annual commencement. In conferring the degree, Dr. Ernst Weber, president of the Polytechnic Institute of Brooklyn, cited Dr. Warnecke "in recognition of his vital contributions to the electronic art and his accomplishments as director of one of the world's great installations."

Dr. Warnecke joined the French Wireless Company in 1927. He became director of the Tubes Research Laboratory in 1933 and chief engineer for research in 1946.

His contributions to the field were recognized by the Institute of Radio Engineers when he was elected a Fellow in 1950. In 1954 he was awarded the Morris Liebmann Prize for the most valuable contributions to radio engineering.

❖

W. B. Nottingham (A'37–SM'46–F'56) has been appointed a consultant to the National Research Corporation.

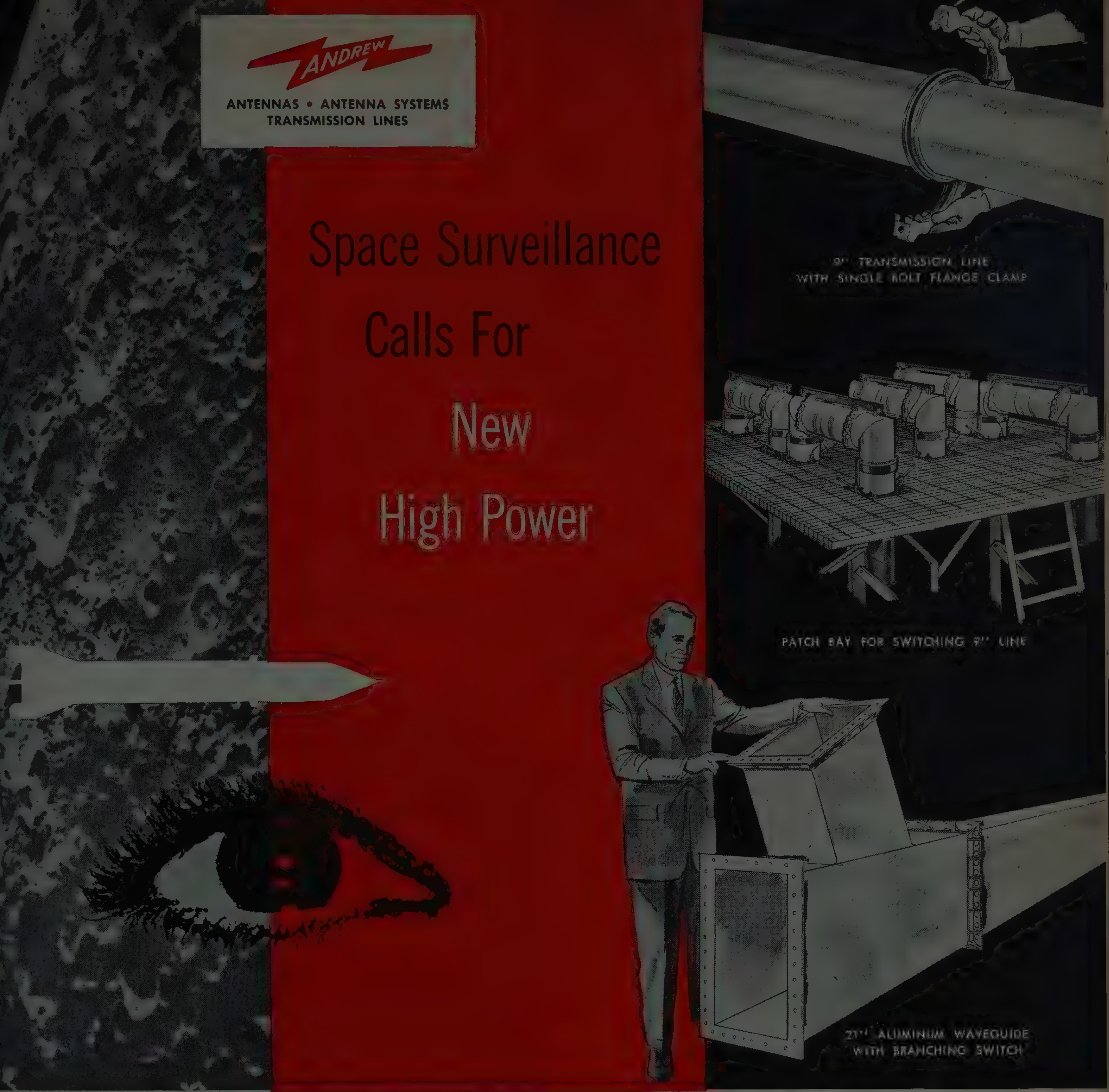
Dr. Nottingham, a professor of physics at M.I.T. and former vice-president in charge of research for Electronics Corporation of America, is well known for his work on extremely low pressure equipment. He devised the Nottingham gauge, an electronic pressure measuring device which operates successfully in vacuum of about 10^{-10} millimeters of mercury or about one ten-trillionth of atmospheric pressure.

Dr. Nottingham will contribute expert counsel on the design of extreme altitude test facilities and will make available to the company a source of important scientific knowledge in electron physics, thermionic emission, gas discharges, photoelectric effects and field emissions.

Dr. Nottingham received a Bachelor of Science degree in physics at Purdue University in 1920, and his doctorate at Princeton in 1929. He was a Franklin Fellow of the American-Scandinavian Foundation, Upsala, during 1920–21, and a Bartol Research Foundation Fellow, Franklin Institute, during 1926–31. He has been on the teaching staff at M.I.T. since 1931 and will continue this association. He was a civilian with the Office of Scientific Research and Development in 1944. He is a Fellow of the American Physical Society and American Academy of Science, and a member of the American Optical Society and Association of Physics Teachers.

❖

(Continued on page 48A)


ANDREW
ANTENNAS • ANTENNA SYSTEMS
TRANSMISSION LINES
Space Surveillance
Calls For
New
High Power
9" TRANSMISSION LINE
WITH SINGLE BOLT FLANGE CLAMP
PATCH BAY FOR SWITCHING 9" LINE
21" ALUMINUM WAVEGUIDE
WITH BRANCHING SWITCH

ANDREW CORPORATION offers a wealth of engineering experience in the field of super power RF transmission devices. A broad line of standard equipment is offered and ANDREW facilities for the development and production of special equipment are without equal.

Available on a production basis is antenna equipment in all of the new, very large waveguide and transmission line sizes, including high power coaxial lines designed with specially shaped inner conductors and insulators to substantially increase voltage ratings.

Typical too, of this equipment are patch panels such as the 9" line model shown above, used for occasional rearrangement of antenna and transmitter connections.

For high speed circuit switching, ANDREW has developed peak reliability, non-contacting waveguide switches such as the 21" model above. Similar switches are also supplied with transitions for use with coaxial line.

Of definite advantage to you is the completeness of the ANDREW line which permits a systems approach with integrated equipment for best performance of the overall system.

Our newly expanded production facilities assure prompt deliveries.

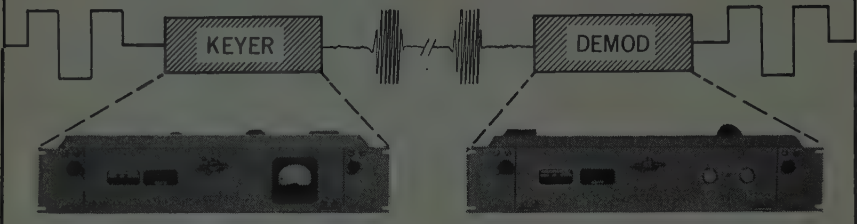
We would welcome your inquiries for product information and engineering assistance on:

Antennas • Feed Horns • Switches • Patch Panels • Duplexers • Power Dividers • Filters • Coaxial Line • Waveguide • Transitions • Adaptors • Bends • Hangers • Dehydrators

VISIT OUR WESCON BOOTH NO. 1215

Andrew
CORPORATION
363 EAST 75TH STREET • CHICAGO 19
New York • Boston • Los Angeles • Toronto

For Transmission . . . .
Of Data Over Communication Circuits



KY-612 TONE KEYER — TD-635 TONE DEMODULATOR

A transistorized system—basic principle of operation is audio frequency subcarrier, keyed on and off. Input and output a-f filters designed for multiplex operation. Up to six 1000 bit multiplex channels in 20 kc band—more channels at lower data rates.

CONDENSED SPECIFICATIONS

Maximum Data Rate (keying Speed)	1000 bits/sec (500 cps square wave)
Input-Output Signal	±20 volts d-c
Carrier Frequencies	Between 1.5 and 20 kc at frequency intervals approximating 3x MUX bit rate
AF Output-Input Levels	—24 dbm to +6 dbm on 600-ohm balanced line
Primary Power (each unit)	105-135 volts a-c, 6 watts
Dimensions (each unit)	19″ x 3½″ x 8″

Ask for Engineering Bulletin No. 57

RIXON ELECTRONICS, INC.
2414 Reedie Drive — Silver Spring, Maryland

Electrically Conductive Cloth

A New Engineering Material for Many Applications in Electronics

SUGGESTED USES:
- RF SHIELDING
- RADAR REFLECTION
- MICROWAVE GASKETING
- WARNING SYSTEMS
- ATTENUATORS
- STATIC DISCHARGE

Buy it by the yard and sew it to shape on any sewing machine. Or, have us sew it for you.

WRITE OR PHONE
Swift
Textile Metalizing
& Laminating Corp.
10 Love Lane, Hartford 1, Conn.
JAckson 2-1181

IRE People

(Continued from page 46A)

R. R. Pecorini (M'54) was recently appointed to the Most Excellent Order of the British Empire (M.B.E.) in a recent Honours List by Queen Elizabeth II, for his work with the Ministry of Supply.

❖

M. S. Friedland, President of the Instrument Corporation of Florida, Melbourne, Fla., recently announced the appointment of **J. H. Reber** (S'47–A'49–M'55), to the position of Vice-President of Electronics Division. He was formerly executive engineer with the corporation. In this new position Mr. Reber is responsible for the research, development and manufacturing of all electronic products. He was appointed a member of the Board of Directors early this year.

J. H. Reber

Immediately prior to joining Instrument Corporation of Florida in late 1957 Mr. Reber was Southeastern District Manager for Applied Science Corporation of Princeton. From 1954 to 1956 he held the position of manager of the Telemetry Data Receiving and Storage Engineering Unit with RCA Missile Test Project at Patrick Air Force Base, Fla. For five years prior to 1954, he was Project Engineer on Airborne Television Reconnaissance Systems at Wright Air Development Center.

He is a graduate of Purdue University, where he received a B.S.E.E. degree in 1948 and an M.S.E.E. degree in 1949. He holds membership in Sigma Xi, Tau Beta Pi and Eta Kappa Nu.

❖

L. R. Everingham (SM'56), for the past year a technical advisor for Radiation, Inc., has been appointed vice-president for research of the Florida electronics firm. Formerly an assistant director and head of tactical air research at the Cornell Aeronautical Laboratory, he has also acted as a consultant to the Air Navigation Development Board. He is a member of the Department of Defense Technical Advisory Panel for Aeronautics, the Radio Technical Commission for Aeronautics and the President's Airport Advisory Committee.

❖

Use your

IRE DIRECTORY!

It's valuable!

NOW... from **Transitron**

the world's

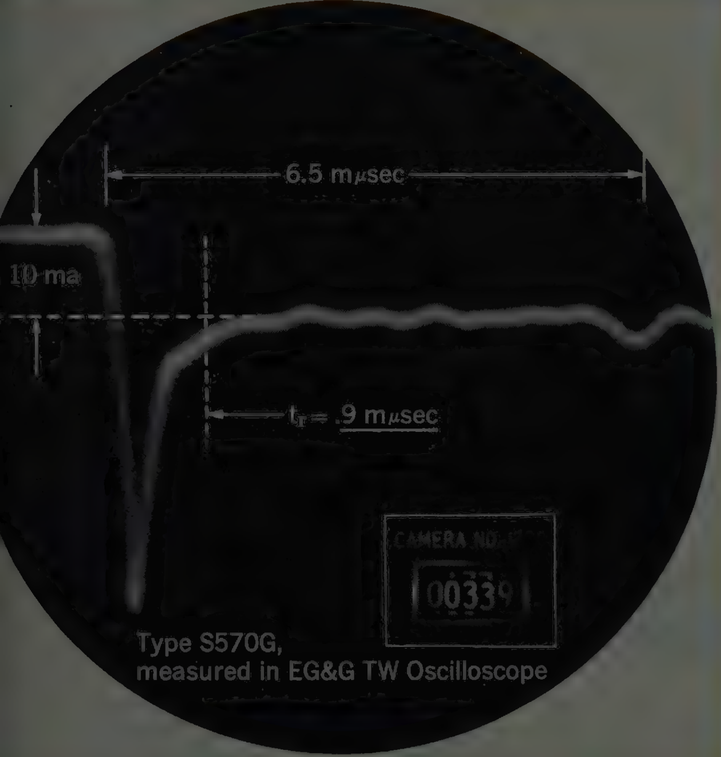
FASTEST DIODES

for milli-microsecond switching!

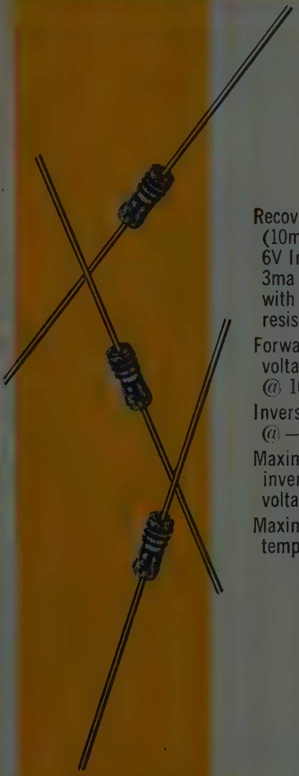
Here at last are diodes suitable for extremely high speed transistorized computer circuitry. These diodes offer you the convenience and simplicity of conventional types — but they are on the order of *50 times faster!* Produced and priced for computer use, they are intended for critical applications at normal transistor bias levels.

The S570G germanium diode has optimized switching characteristics in the region below 10 milli-microseconds. Total stored charge after a 10ma forward current is less than that of a 3pf (micro-microfarad) capacitor at 6 volts! Germanium type S555G obtains better D.C. characteristics at some sacrifice of speed. The S266G is a bonded silicon diode intended for use in high temperature high speed equipment. Low leakage current makes it useful also as a pulse stretcher. It is typically faster than any of the presently available silicon diffusion diodes and silicon transistors.

These new diodes can reduce the number of transistors in circuits. They may be used to simplify coupling and logic design, reducing dependence on critical timing and synchronization. For example, difficult DCTL circuits may be made DCDTL with no loss in speed. *Available now,* these diodes will open many new frontiers.



Type S570G, measured in EG&G TW Oscilloscope



	GERMANIUM		SILICON
	S570G	S555G	S266G
Recovery time (10ma I_{fwd}, 6V Inverse to 3ma Inverse with 120 ohms resistive load)	.002	.006	.004 μsec max.
Forward voltage drop @ 10ma	1.0	.5	1.5 volts max.
Inverse current @ −6 volts	30.0	10.0	1.0 μa max.
Maximum inverse voltage rating	8.0	15.0	8.0 volts
Maximum temperature	75	75	150 °C

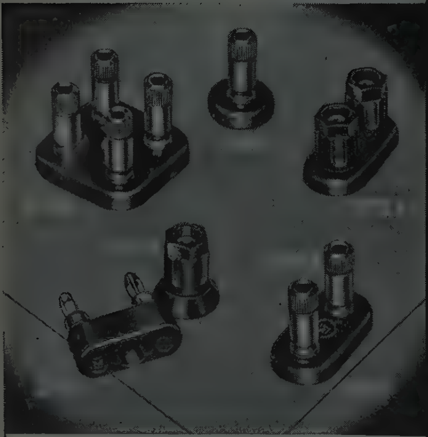
Transitron

electronic corporation wakefield, massachusetts

Transistors
Diodes
Regulators
Rectifiers

SEE US AT THE WESCON SHOW—BOOTHS 1567-68

Designed for Application



BINDING POSTS, PLATES AND PLUGS

The Millen "Designed for Application" connectors include the No. 37223 Insulated Binding Post shown with the No. 37291 individual insulator and the No. 37202 dual insulator plate. Also shown above are the No. 37201 individual insulators for the No. 37222 metal binding posts and the four-terminal plates, No. 37204, for either the insulated or metal binding posts. The No. 37212 two-terminal plug is for use with the two-terminal or four-terminal assemblies. The insulator plates, plugs, and insulated binding posts are available in black or red. The No. 37212 plugs and the No. 37202 and No. 37204 plates are also available in low loss mica filled natural color phenolic for radio frequency applications. Other colors are available upon request. The No. 37202 plates are also available in steatite ceramic. Both the insulated and the metal binding posts have captive heads.

JAMES MILLEN
MFG. CO., INC.

MAIN OFFICE AND FACTORY
MALDEN
MASSACHUSETTS

Industrial Engineering Notes*

EIA Activities

Concluding a well attended 34th annual convention, the EIA Board of Directors elected David R. Hull, Vice-President of the Defense Programs of Raytheon Manufacturing Co., President to succeed Dr. W. R. G. Baker, who concluded his second term, and other officers who will direct the Association's operations during 1958–59. Four new Vice-Presidents, 16 new Directors, and three new Division Chairmen also were elected along with the re-election of other officers. A new office of Senior Vice-President was created to provide a presiding officer in the absence of the President, and Director Robert S. Bell, chairman of the Consumer Products Division, was named to this post. Four EIA department heads were re-elected and a new department Director was named also by the Board of Directors. Dr. Baker was re-elected Director of the Engineering Department as were the following three Directors of the other departments: Frank W. Mansfield, Marketing Data; C. Paul Young, Military Relations; and Ray C. Ellis, International. John H. Winant, of the Sprague Electric Company, was elected Director of the Industrial Relations Department. Treasurer Leslie F. Muter was re-elected for his 23d term, and both Executive Vice-President James D. Secrest and General Counsel William L. Reynolds also were re-elected. The four new Vice-Presidents and their Divisions are: Sidney R. Curtis, Stromberg-Carlson Company, Military Products; Russell E. Cramer, Jr., Radio Condenser Company, Parts; A. L. Chapman, CBS-Hytron, Tube and Semiconductor; and C. Russell Cox, Andrew Corporation, Technical Products. Mr. Curtis also was elected Chairman of the Military Products Division, and Director L. L. Waite, of North American Aviation, Inc., was elected Vice-Chairman. Other new Division Chairmen are: Ben Adler, Adler Electronics, Technical Prod-

(Continued on page 52A)

---

* The data on which these NOTES are based were selected by permission from *Industry Reports*, issues of May 26, and June 9, 16 and 23, published by the Electronic Industries Association whose helpfulness is gratefully acknowledged.

COLOR TV SHADOW MASKS

—A development of BUCKBEE MEARS through close cooperation with TV industry engineers. Containing 400,000 close tolerance holes (.010" ± 0005"). Now produced in quantity on our especially designed continuous etching machines.

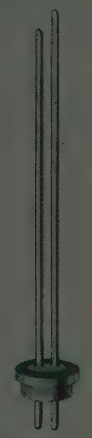
BUCKBEE MEARS COMPANY

TONI BUILDING
SAINT PAUL 1, MINN.

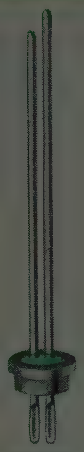
ETCHED AND ELECTRO-FORMED PRECISION PARTS

—Electric shaver combs, metal reticles for optical instruments, fine tube mesh and code discs. These are but a few of the variety of parts that can be quickly produced to precise tolerances by our process. Send your specific problem and specifications to our engineers.

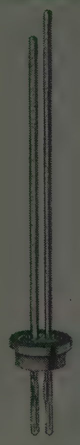
How US SEMCOR assembles a Silicon Diode with ALL STAINLESS STEEL FUSITE TERMINAL



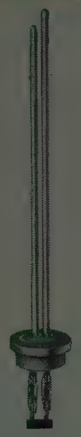
1. *Terminal as supplied by Fusite. V-24 glass and all stainless steel.*



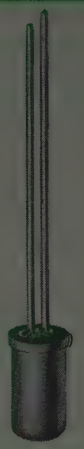
2. *Inside end of straight wire electrode is crimped to a hollow open top shell. (See photo A)*



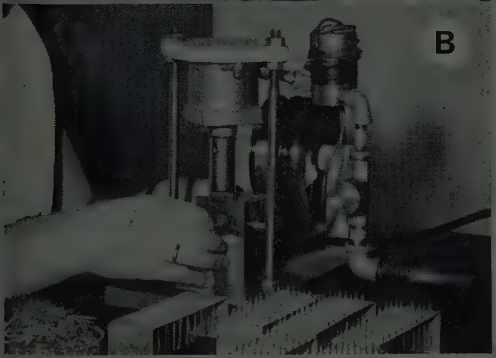
3. *Fraction of an inch of gold wire and aluminum wire are inserted and crimps folded over tight. (See photo B)*



4. *Precision bit of silicon crystal is fused with heat to ends of wire inserts.*



5. *Assembly is enclosed in miniature can and projection welded closed.*



This application is typical of the hundreds of electronic components whose continuing operation is assured by the safety factor of a terminal with electrodes fused into the glass. The resulting rigidly fixed position of the electrode guards against damage to the finished assembly through movement of an electrode depending only on compression for its position in the glass.

Robert A. Rutherford, Vice President of U. S. Semiconductor Products, permits us this direct quotation.

"The Fusite header provides us with a very satisfactory solution to the problem of the lead wires turning in the header. The fused glass to steel has solved this very troublesome problem. The stainless steel material also provides excellent corrosion resistance. Aside from receiving a superior product from Fusite, we have also received very excellent service and a great deal of cooperation from both the company and their representative."

Test samples of any style terminal available on request. Stainless steel available on most Fusite Standard Headers.

Write Dept. G-2

GLASS TO METAL
FUSITE
TERMINALS
PROTECT PRODUCT PERFORMANCE

THE FUSITE CORPORATION

6000 FERNVIEW AVE., CINCINNATI 13, OHIO

In Europe: FUSITE N.V. Königweg 16, Almelo, Holland

THE SHOEBOX

goes anywhere!

"talk about top performance!"
"it's practically weightless!"
"a sea-full of big scope features!"
SIG
MS ▼/ DIV
SYNC

Less than 8 lbs.

4¾" H
5½" W
10" D

RUGGED NEW
DIRECT READING, HI-GAIN

POCKETSCOPE

Waterman S-17-A

SHOEBOX SIZE—LARGE SCOPE PERFORMANCE

- DIRECT READING IN VOLTS AND MILLISECONDS
- DC TO 250 KC—FROM 10 MV P-P
- 10 SECONDS TO 10 MICROSECONDS
- DUAL-DIAL, HE-MAN CONTROLS
- AUTO-SYNC
- $295.00

Get all the facts about this outstanding, *really portable* OSCILLOSCOPE.

See Authorized Distributor.

WATERMAN PRODUCTS CO., INC.

PHILADELPHIA 25, PA. • GArfield 6-8600

Manufacturers of PANELSCOPE* PANELPACK* POCKETSCOPE* PULSESCOPE* RAKSCOPE* SYSTEMAT* CRAFTSCOPE* RAYONIC TUBES*
. . . And Other Associated Equipment
*Registered Trademarks

WATERMAN PRODUCTS

(Continued from page 50A)

ucts; and William S. Parsons, Centralab Division of Globe Union Inc., Parts. Director Bell was re-elected Chairman of the Consumer Products Division, and D. W. Gunn was re-elected Chairman of the Tube and Semiconductor Division. . . . **Working cooperatively with a printing establishment in the Washington area, EIA completed necessary arrangements to make available to all segments of the communications industry the "Frequency Assignment Lists" prepared semi-annually by the FCC.** The EIA decision to sponsor the project results from actions taken in Chicago by the Technical Products Division. EIA's participation will be on a non-profit basis and the "lists" will be made available, through subscription, for the first time to the general public, particularly to all segments of the industry including: manufacturers, consulting engineers, attorneys practicing before the FCC, user groups, frequency coordinating and advisory groups, and domestic and international common carriers. Formerly issued in six volumes and only on a frequency basis, the lists covered the entire spectrum of non-government frequency assignments. The FCC changed its procedure in January of this year to establish the lists on a "Services" basis. Currently, there are 14 volumes covering the entire field of radio communications. They detail the frequencies in numerical order, data of issue and call signs where applicable, geographical locations by town or city and state, coordinates in longitude and latitude, and technical information as to emission and power. A cross reference will establish the identification of the licensee. The service ranges in price from $2.48 for the volume on "Marine Service List" to $28.73 for "Public Safety Service List" and is priced according to the number of pages in each volume. In order that this service can be made available on a cost basis through subscription, it is necessary to determine requirements before printing. Additional information can be obtained by writing D. H. Stover, EIA Headquarters, Washington, D. C.

ENGINEERING

The following persons were appointed to serve on the Joint Technical Advisory Committee for the two-year period July 1, 1958 to June 30, 1960, according to JTAC Secretary L. G. Cumming, of the IRE: Representing EIA, John V. L. Hogan named JTAC Vice Chairman, Hogan Laboratories, Inc.; Ira J. Kaar, Hoffman Electronics Corp., reappointed; Arthur V. Loughren, Airborne Instruments Laboratory, Inc., reappointed, and Dr. William H. Radford, Lincoln Laboratory, MIT. Representing the IRE: Philip F. Siling named Chairman, RCA Frequency Bureau; Dr. Ralph Brown; Dorman D. Israel, Emerson Radio and Phonograph Corp., and Dr. Ernst Weber, Polytechnic Institute of Brooklyn.

(Continued on page 54A)

OPEN NEW HORIZONS IN CIRCUITRY...

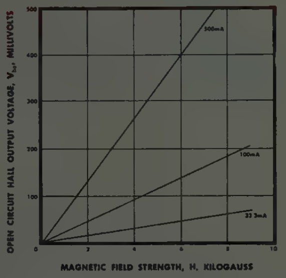
Halltron

TYPE HS-51

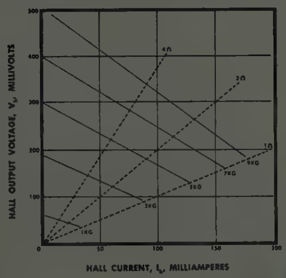
NEW SEMICONDUCTOR DEVICE...

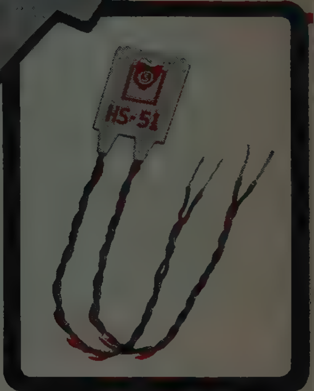
ical Room Temperature Characteristics

l open circuit Hall
voltage of an HS-51
n vs. magnetic field
n for various values
control current, I_c.



Hall output voltage
n HS-51 Halltron vs.
l output current for
values of magnetic
ld strength. Control
urrent, $I_c = 500^{m}A$.





Type HS-51 Halltron, actual size.

The HALLTRON is a new semiconductor device based upon the Hall effect. The output characteristics of the HALLTRON are a function of both the input current and the applied magnetic field. Because of this dependence of the output upon the multiple inputs, many new circuit applications are envisioned, as well as improved means for performing known circuit functions. The type HS-51 HALLTRON uses an active element of indium antimonide in the form of a small, thin wafer. The extremely high mobility of this material, first developed commercially by O.S.I., leads to remarkable performance characteristics. The HS-51 is a fully-developed, production unit designed with an awareness of application engineering. The unit was designed to work in the customer's magnetic circuit and accordingly was made thin to utilize small magnetic gaps and minimize the magnetic circuit requirements.

Applications of the HS-51 HALLTRON include:

- **DC to AC converters**
- **magnetic field measurement**
- **control applications**
- **computer applications**
- **gyrators**
- **circulators**
- **power meters**
- **transducers**

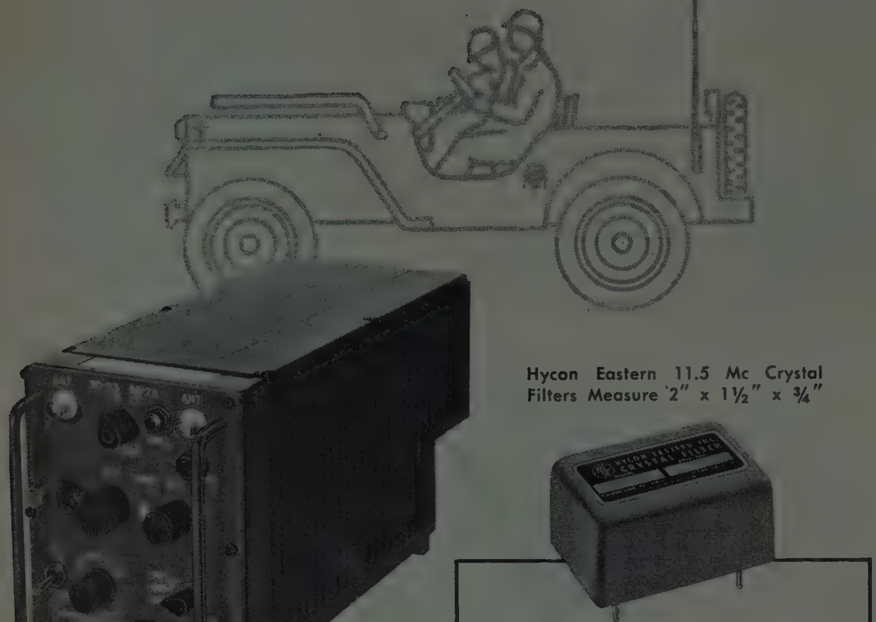
Write for detailed application information on the HS-51 Halltron.

OHIO SEMICONDUCTORS, INC.

1035 W. THIRD AVENUE • COLUMBUS 8, OHIO

Pioneer in the development and manufacture of compound semiconductors for

FIRST 920 Channel Single Conversion VHF Mobile Receiver Uses HYCON EASTERN CRYSTAL FILTER



Hycon Eastern 11.5 Mc Crystal Filters Measure 2″ x 1½″ x ¾″

VHF, 920 Channels, fully transistorized Radio Receiver by Avco Mfg. Corp., Crosley Division

Bandwidth at 6 db attenuation: 33 Kc
Bandwidth at 60 db attenuation: 60 Kc
Insertion Loss: 4 db
Ultimate attenuation: 80 db

Mobile communications for today's fast moving military operations require equipment which is rugged, compact, highly accurate and dependable. Filling this need is the Avco-Crosley, fully transistorized, 920 channel, mobile VHF-FM Radio Receiver incorporating a Hycon Eastern 11.5 Mc Crystal Filter and matching Discriminator.

The use of only one frequency conversion provides excellent image rejection in combination with high adjacent channel selectivity. By eliminating multiple conversions, cross modulation and receiver desensitization are reduced even in the the presence of strong interference from any of the other 920 channels.

High Frequency Crystal Filters for mobile applications offer the advantages of small size, freedom from microphonic behavior, and ability to maintain their characteristics throughout the entire temperature range of −60°C to +90°C. Hermetically sealed, no realignment or readjustment is ever required.

There are Hycon Eastern Crystal Filters designed to solve selectivity problems in AM or FM receivers and SSB transmitters, whether fixed or mobile. Hycon Eastern engineers can assist you in choosing filter characteristics best suited to your needs. Write for Crystal Filter Bulletin.

HYCON EASTERN, INC.
75 Cambridge Parkway
Dept. B
Cambridge 42, Mass.

Industrial Engineering Notes

(Continued from page 52A)

GOVERNMENT

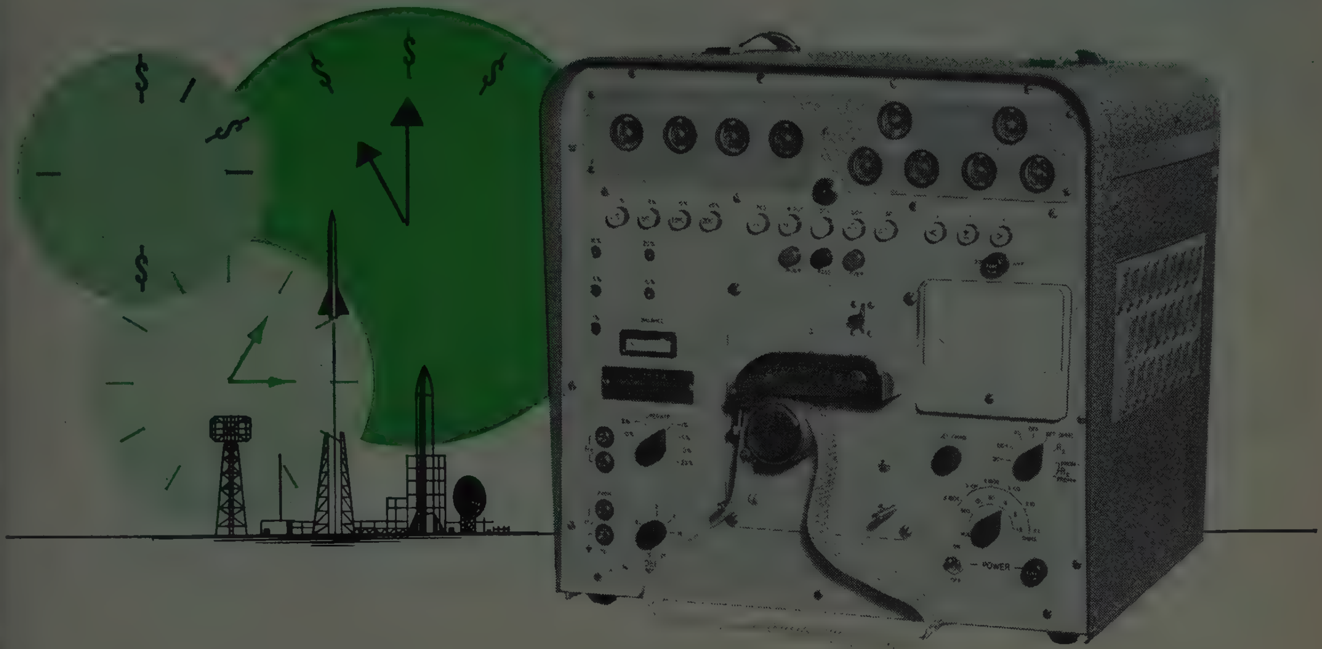
Who buys what and where in the federal government is told in a publication announced by the Small Business Administration. Entitled "U. S. Government Purchasing and Specifications Directory," the booklet also lists the offices where individuals and firms interested in providing goods or services to the government can obtain or review specifications covering the government's purchases. The booklet costs 25 cents and can be obtained from the GPO, Washington 25, D. C. . . . **The Television Allocations Study Organization (TASO) completed arrangements with the University of Texas, in Austin, whereby the University, through its Bureau of Engineering Research, will undertake the analysis of the UHF and VHF propagation data which have been taken by TASO and by those working in collaboration with TASO.** The University of Texas has a deservedly high reputation for its research in the field of wave propagation and has a staff which has contributed greatly to the present knowledge of this phase of the art of electrical communications, TASO Director Dr. G. R. Town said. The field strength measurements which are to be analyzed, and upon which new propagation curves applicable within the service range of television transmitters will be based, have been taken in many areas of the country by many groups. These include the Association of Maximum Service Telecasters, CBS Television, Westinghouse Broadcasting Company, the FCC and individual UHF and VHF stations and their engineering consultants. The analysis of the data is the responsibility of TASO Panel 5—Analysis and Theory. The work at the University of Texas represents one part of the activities of this TASO Panel.

MARKETING

For the first time in the history of transistor production, factory sales of these semiconductor devices dropped from the previous month—April compared with March of this year. This did not affect the over-all cumulative totals during the first four months of this year which were substantially over the like 1957 period. Factory sales of transistors in April totaled 2,856,234 units with a dollar value of $7,025,547 compared with 2,976,843 units valued at $6,795,427 sold in March and 1,774,000 units valued at $4,880,000 sold in April, 1957. Cumulative sales of these semiconductor devices totaled 11,895,032 units valued at $27,331,919 sold during the first four months of this year compared with 6,899,000 transistors sold with a value of $19,492,000 during the corresponding four months of 1957. . . . **Factory production of both radio and television receivers in April declined from the March output of these items and was**

(Continued on page 56A)

"beat the clock" on every electronic test



NEW *Lavoie* ROBOTESTER SLASHES TEST TIME AND EXPANDS CHECKOUT CAPABILITIES

CUTS

FINAL TEST

TIME

80%

The new Lavoie Robotester brings a fresh viewpoint to operational testing and production line checkout through continuous, high-speed sampling and comparison . . . split-second recognition, isolation, and identification of abnormal functions — with the added versatility and flexibility of **pre-programmed** acceptance standards.

Nominal circuit values and specified tolerances are tape-punched **in minutes** to accommodate voltages (AC and DC) from 0.5 to 500 volts; resistances from 1 ohm to 9.99 megohms; and tolerances of 1%, 5%, 10%, and 20% of nominal. The Robotester will check any two of 250 circuit points at rates up to 100 tests per minute. Automatic operation stops when an out-of-tolerance value is met, while nixie-tube readout identifies the isolated, faulty circuit.

The high speed of the Robotester means a saving of up to 80% of your production test time or a five-fold increase in test capabilities . . . **NOW.**

A state-of-the-art
ADVANCE
with unlimited
applications

In research, development, manufacturing
In avionics, communications, missile count-down
In design, production, maintenance

Lavoie Laboratories, Inc.

MORGANVILLE, NEW JERSEY

DESIGNERS AND MANUFACTURERS OF ELECTRONIC EQUIPMENT

See us at Wescon, Booth 1503

FREED

MIL-T-27A POWER, FILAMENT, PULSE & AUDIO TRANSFORMERS

FOR IMMEDIATE DELIVERY FROM STOCK

POWER TRANSFORMERS-STANDARD
All primaries 105/115/125 v., 60 c.p.s.

Cat. No.	Hi Volt Sec.	ct	DC Volts	DC Amps	Filament #1 Volt	Filament #1 Amp.	Filament #2 Volt	Filament #2 Amp.	MIL Case Size
MGP1	400/200	√	185	.070	6.3/5	2	6.3	3	HA
MGP2	650	√	260	.070	6.3/5	2	6.3	4	JB
MGP3	650	√	245	.150	6.3	5	5.0	3	KB
MGP4	800	√	318	.175	5.0	3	6.3	8	LB
MGP5	900	√	345	.250	5.0	3	6.3	8	MB
MGP6	700	√	255	.250					KB
MGP7	1100	√	419	.250					LB
MGP8	1600	√	640	.250					NB

FILAMENT TRANSFORMERS-STANDARD
All primaries 105/115/125 v., 60 c.p.s.

Cat. No.	Secondary Volt	Secondary Amp	Test VRMS	MIL Case
MGF1	2.5	3.0	2,500	EB
MGF2	2.5	10.0	2,500	GB
MGF3	5.0	3.0	2,500	FB
MGF4	5.0	10.0	2,500	HB
MGF5	6.3	2.0	2,500	FB
MGF6	6.3	5.0	2,500	GB
MGF7	6.3	10.0	2,500	JB
MGF8	6.3	20.0	2,500	KB
MGF9	2.5	10.0	10,000	JB
MGF10	5.0	10.0	10,000	KB

PULSE TRANSFORMERS

Cat. No.	Block'g. Osc.	Int. Coupl'g	Low. Pow. Out.	[redacted] Voltage Kilovolts	Pulse [redacted]	Duty Rate	No. of Wdgs.	Test Volt. KVRMS	Char. Imp. Ohms
MPT1	√	√		0.25/0.25/0.25	0.2-1.0	.004	3	0.7	250
MPT2	√	√		0.25/0.25	0.2-1.0	.004	2	0.7	250
MPT3	√	√		0.5/0.5/0.5	0.2-1.5	.002	3	1.0	250
MPT4	√	√		0.5/0.5	0.2-1.5	.002	2	1.0	250
MPT5	√	√		0.5/0.5/0.5	0.5-2.0	.002	3	1.0	500
MPT6	√	√		0.5/0.5	0.5-2.0	.002	2	1.0	500
MPT7	√	√	√	0.7/0.7/0.7	0.5-1.5	.002	3	1.5	200
MPT8	√	√	√	0.7/0.7	0.5-1.5	.002	2	1.5	200
MPT9	√	√	√	1.0/1.0/1.0	0.7-3.5	.002	3	2.0	200
MPT10	√	√	√	1.0/1.0	0.7-3.5	.002	2	2.0	200
MPT11	√	√	√	1.0/1.0/1.0	1.0-5.0	.002	3	2.0	500
MPT12	√	√	√	0.15/0.15/0.3/0.3	0.2-1.0	.004	4	0.7	700

AUDIO TRANSFORMERS

Frequ. resp. 300 to 10000 cps ± 2 DB. All Case Sizes AJ

Catalog No.	Application	Impedance Prim. Ohms	Impedance Ct.	Impedance Sec. Ohms	Impedance Ct.	DC Current Prim. P. Side MA	DC Current Max. Unbal. MA	Max. Level DBM
MGA1	Single or P.P. Plates — to Single or P.P. Grids	10K	√	90K Split	√	10	10	+15
MGA2	Line to Voice Coil	600 Split		4, 8, 16		0	0	+33
MGA3	Line to Single or P.P. Grids	600 Split		135K	√	0	0	+15
MGA4	Line to Line	600 Split		600 Split		0	0	+15
MGA5	Single Plate to Line	7.6K 4.8T		600 Split		40	40	+33
MGA6	Single Plate to Voice Coil	7.0K 4.8T		4, 8, 16		40	40	+33
MGA7	Single or P.P. Plates to Line	15K	√	600 Split		10	10	+33
MGA8	P.P. Plates to Line	24K	√	600 Split		10	1	+30
MGA9	P.P. Plates to Line	60K	√	600 Split		10	1	+27

Send for further information on these units, or special designs. Also ask for complete laboratory test instrument catalog.

FREED
TRANSFORMER CO., INC.
1720 Weirfield Street
Brooklyn (Ridgewood) 27, New York

Industrial Engineering Notes

(Continued from page 54A)

down somewhat from the level of April, 1957. Output during the first four months of this year was also under the 1957 level. Television production in April totaled 302,559 compared with 416,903 TVs made in March and 342,386 television units produced in April, 1957. The number of TV sets made with UHF tuners totaled 22,296 in April compared with 36,050 in March and 42,374 produced in April, 1957. Cumulative TV production during the first four months of this year amounted to 1,523,858 compared with 1,835,975 TVs made during the like 1957 months. Radio receiver production in April totaled 697,307 including 190,435 auto sets, compared with 931,341 radios made in March which included 234,911 auto sets and 1,115,813 radios produced in April 1957, which included 380,452 automobile receivers. Cumulative radio receiver production during the first four months of this year totaled 3,532,066, including 1,043,470 auto receivers, compared with 5,075,180 radios made during the like four-month period in 1957, which included 2,022,467 auto receivers. . . . **The Bureau of Labor Statistics has released figures covering employment in the communications equipment industry which shows the total number of employes in March to be 531,500 compared with the 537,400 employed in February and 564,900 employed by the industry in March, 1957.** Production workers totaled 343,500 in March compared with 350,800 in February and 386,500 such workers employed in March a year ago, the BLS reported.

Section Meetings

AKRON

"Game Theory," F. Brooks, Kent State Univ.; 5/20/58.

ALAMOGORDO-HOLLOMAN

"A Look into the future of Electronic Standardization," H. W. Lance, Nat'l. Bureau of Standards; 5/21/58.

BALTIMORE

"Experiences during an expedition to Middle East with Lowell Thomas," Traveltalk, Mr. & Mrs. W. Terry, Am. Soc. for the Study of Man; 5/10/58.

"Radio Astronomy and The Maser," H. I. Ewen, Ewen-Knight Corp.: 6/11/58.

BEAUMONT-PORT ARTHUR

Annual Dinner and Election of Officers; 5/20/58.

BINGHAMTON

"Inertial Guidance for Space Vehicles," C. S. Draper, M.I.T.; 5/12/58.

"Recording Techniques," W. H. Miltenburg, R.C.A. Victor; 6/9/58.

BUFFALO-NIAGARA

"The Transistor and the Circuit Application Engineer," F. L. Abboud, Sylvania Elec. Prod.; "Transistorizing the Synchronizing & Horizontal Osc. Stages of a T.V. Receiver," D. Swaine, Sylvania Elec. Prod.; 5/21/58.

CEDAR RAPIDS

"Electronics in Long Range Weather Forecasting and Cloud Seeding," N. C. Stone, Irving P. Krick Assoc. Inc.; "New Dimensions in Electronics," Color Film.; 3/19/58.

"Logarithmically Periodic Antennas," R. DuHamel, Collins Radio Co.; "The Radio Sextant," G. Marner, Collins Radio Co.; 4/16/58.

CENTRAL FLORIDA

"Education for the Preservation of Life," J. Weil, Univ. of Fla.; 3/20/58. Annual Dinner-dance; 4/18/58.

"Radar Reflectivity Measurements," R. Evans, Radiation Inc.; 5/22/58.

CENTRAL PENNSYLVANIA

"New Adventures in Electronics," C.N. Hoyler, RCA Labs.; 5/22/58.

CHINA LAKE

"History of Magnetic Tape," B. Kelley, Reeves Soundcraft; 6/16/58.

COLOMBIA

"VHF Communications," a film, RCA; 11/15/57.

"The Ionosphere and its Importance in Radio Communications," Wladimiro W. Escobar, S. J., Inst. Geofisco de Los Andes; 1/31/58.

"High Frequency Ionospheric Propagations," A Villegas, RCA; 3/21/58.

"R.F. Antennas," G. Piquero; 4/24/58.

COLUMBUS

"Inertial Navigational Computers," H. R. Brown, North American Aviation; 4/17/58.

"Tour of Facilities, History, Evolution of Industrial TV Product, Line of Diamond Power by principals; 5/6/58.

DAYTON

"Some Unsolved Problems of Engineering Management," J. H. Rubel, Hughes Aircraft Co.; 4/3/58.

DENVER

"IRE Policies," K. V. Newton, IRE Director, Region 6; 6/6/58.

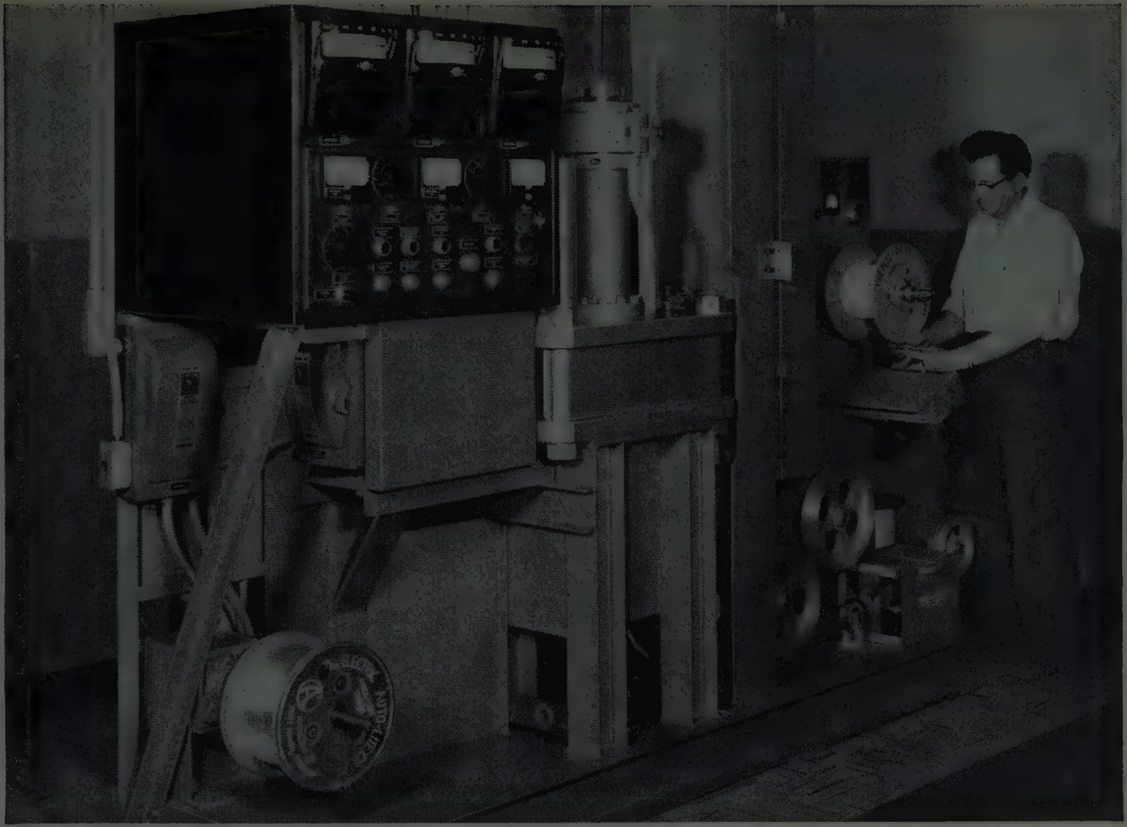
DETROIT

"Electronic Random Number Generator," J. A. Lander, Univ. of Mich.; "Industrial Thermacouple Calibration," W. G. Trabold, Univ. of Detroit; "High Reactance Transformer," J. L. Patrick, Wayne State Univ.; 5/16/58.

ELMIRA-CORNING

"Radio Explores Outer Space," A. E. H. Rydbeck, Chalmers Univ.; 5/15/58.

(Continued on page 58A)



NOW! AN ENGINEERED AND CONTROLLED TEFLON* WIRE

Auto-Lite engineering, plus constant laboratory checking and rigid quality controls assure you of the finest quality Teflon insulations.

Teflon tetrafluoroethylene resins, as applied by Auto-Lite, meet the standards of MIL-W-16878B, Types E and EE, and Class H as designated by AIEE. Teflon wire insulation by Auto-Lite can operate continuously at temperatures higher than 400°F and lower than −80°F and still maintain excellent dielectric properties.

Because of Teflon's high dielectric characteristics, thin wall insulation is effective in simplifying miniaturized component part assemblies. Teflon insulation will not burn, melt or decompose at soldering temperatures; soldering is easier and the danger of accidental grounding minimized.

Auto-Lite applications of Teflon insure a non-inflammable insulation, completely unaffected by sunlight or outdoor weathering. Teflon resins resist corrosion, the growth of fungus, and are free from water absorption by A.S.T.M. test D570-42.

Auto-Lite is equipped to supply extruded or taped types of Teflon insulations in a choice of colors. When you buy Auto-Lite, you buy precision engineering, laboratory and production controls that Auto-Lite uses to manufacture all of its wire and cable products.

*Teflon—Registered trademark of E. I. du Pont de Nemours & Co. (Inc.)

QUICK DELIVERY FROM THESE PLANTS AND WAREHOUSES:

- Port Huron, YUkon 5-6131
- Yonkers, New York, OXford 7-7440
- Chicago, Illinois, WEbster 9-3144
- Hazleton, Pa., GLadstone 5-4781
- Los Angeles, Calif., FAculty 1-2184
- Cincinnati, Ohio, PRinceton 1-8100

AUTO-LITE®

For further information on any of these products write . . .

THE ELECTRIC AUTO-LITE COMPANY
TOLEDO 1, OHIO

WIRE & CABLE ▶ SPECIAL FABRICATIONS ▶ INSTRUMENTS
PLASTICS & NON-METALLICS ▶ FOUNDRY GROUP

McCoy quartz crystals

meet 5 important requirements

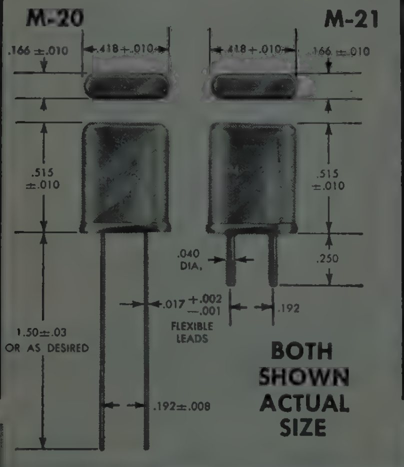
SIZE . . . Less than ½″ wide; please note dimensions below.

WEIGHT . . . One twenty-fifth (1/25) of an ounce.

VIBRATION . . . Withstands from 10 to 2000 c.p.s.

SHOCK . . . Withstands from 0 to 30 g.

STABILITY . . . Frequency stabilities of ±.0025% over —55° C to ±90° C possible.



McCoy McMite lightweight quartz crystals extend the limits of electronic design. These little, hermetically sealed units are built rugged to pack regular size performance into minimum space . . . with no sacrifice of stability or dependability! Produced in frequencies from 3 mc to 125 mc to meet government specifications or made to your own specifications.

McCoy
ELECTRONICS COMPANY
MT. HOLLY SPRINGS, PENNA.
DEPT. P8 PHONE HUnter 6-3411

SEE US AT THE
I.R.E. WESCON
SHOW
BOOTH 1622
PAN-PACIFIC AUDITORIUM
AUGUST 19th to 22nd

Write for Free Illustrated Catalog Today.

Section Meetings

(Continued from page 56A)

EVANSVILLE-OWENSBORO

"Weather Research Expedition to Antarctica," J. A. Shear, Univ. of Ky.; 5/14/58.
Annual Picnic Meeting; 6/8/58.

FLORIDA WEST COAST

"Microwave Instrumentation," A. H. Lynch, Arthur H. Lynch & Assoc., Inc.; 5/21/58.
"Behind the Scenes of the Explorer Launch," B. B. Small, Air Force Missile Test Center, and R. E. Gorman, Missile Firing Lab.; 6/13/58.

FORT WAYNE

"The Impact of the IRE on Technological Progress," Donald G. Fink, IRE President; "Patent Law for Engineers," R. G. Irish, Gust & Irish; 3/18/58.

HAWAII

Annual Meeting: 6/11/58

HOUSTON

"IGY Glaciological Observations in the Antarctic," J. C. Cook, Southwest Research Inst.; 5/20/58.

HUNTSVILLE

"Telemetering Applications Techniques," W. P. Boyer, Bendix Aviation Corp.; 4/29/58.
"Frequency Control in the U.H.F. Region," E. G. Holmes, Edward G. Holmes, Assoc.; 5/27/58.

ISRAEL

"The Doppler Effect and its Application to the Determination of Satellite Trajectories," E. Weissberg, Israel Ministry of Defense; 5/27/58.

ITHACA

"Effects of Solar Emission on the Upper Atmosphere," C. W. Gartlein, Cornell Univ.; 5/15/58.

KANSAS CITY

"Electronic Flight Simulators," R. N. White, Trans. World Airlines; 4/8/58.
"Introduction to the IBM 630 Computer," G. M. Brooks, IBM Corp.; 5/13/58.

LONDON

"Performance and Operation of 'Bach-Simpson 2610 Oscilloscope'," R. W. Wilton, Bach-Simpson Ltd.; 5/6/58.

LONG ISLAND

"Electronics and Controlled Fusion Research," E. W. Herold; 4/15/58.
Field Trip; 5/17/58.
Field Trip; 6/14/58.

LOS ANGELES

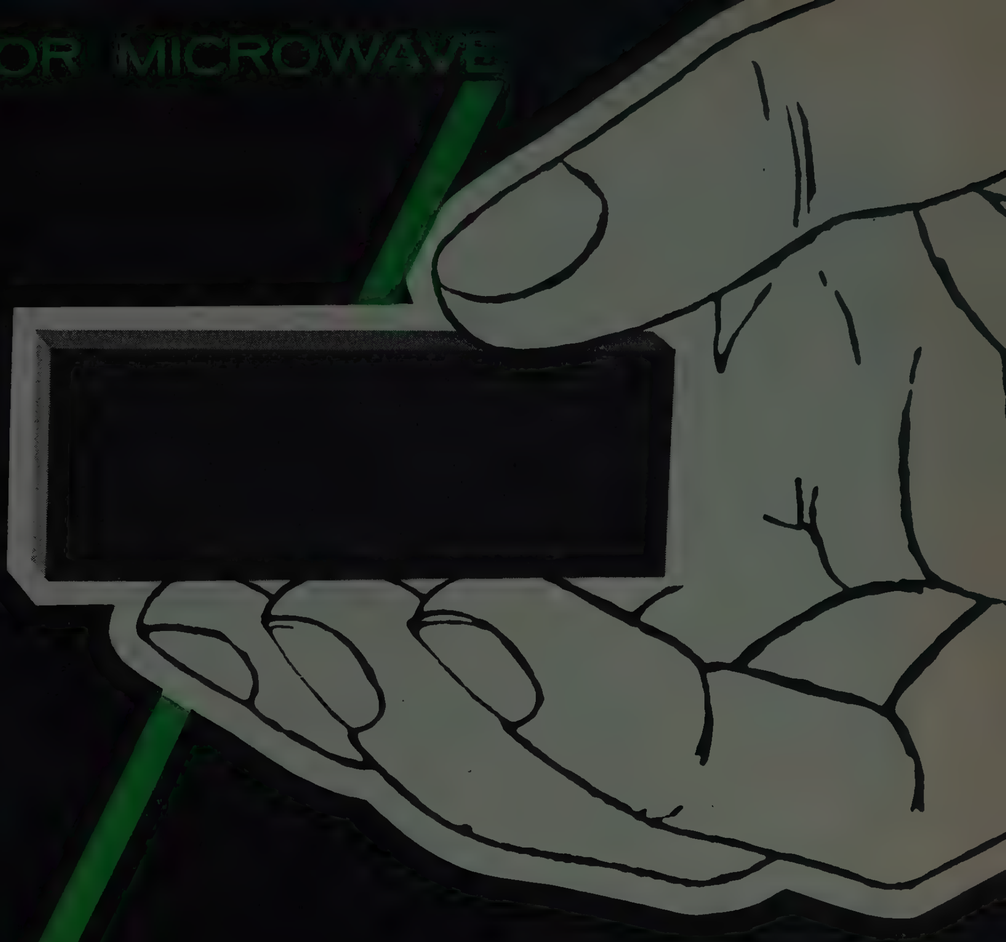
"Trends in Professional Courage," V. J. Braun, Rand Corp.; "Some Problems Involved in the Development of a Computer Program for the Air Defense of the Continental United States," M. O. Kappler, Rand Corp.: 6/3/58.

MIAMI

Third Annual Engineer's Exposition; 2/21/58.
"A Coasting Time Computer," D. C. Colbert, Electronic Communications; 3/21/58.
"Electroluminescence," "Testing Procedures for Magnetic Amplifiers," and "Solar Batteries," J. Bozanic, J. Fridell, R. Newcomb, students, U. of M.; "New Dimensions in Electronics," Collins Radio, a film; 5/29/58.

(Continued on page 62A)

GARNETS FOR MICROWAVE



Polycrystalline YIG
(Yttrium-Iron Garnet)

for

ISOLATORS, ROTATORS, PARAMETRIC AMPLIFIERS and Other Microwave Application

- Lower loss than ferrites in the microwave region.
- Typical Line Widths — 55 oersteds at 9,000 mc.; 30 oersteds at 3,000 mc.
- 100% Ultrasonic Inspection.
- Available in Rectangular or Cylindrical Shapes.

YIG (Yttrium-Iron Garnet), one of a group of rare earth polycrystalline materials, has been found far superior to conventional microwave ferrites in certain applications where extremely low-loss characteristics and a narrow resonance line-width are advantageous. Results heretofore unobtainable can now be commercially achieved.

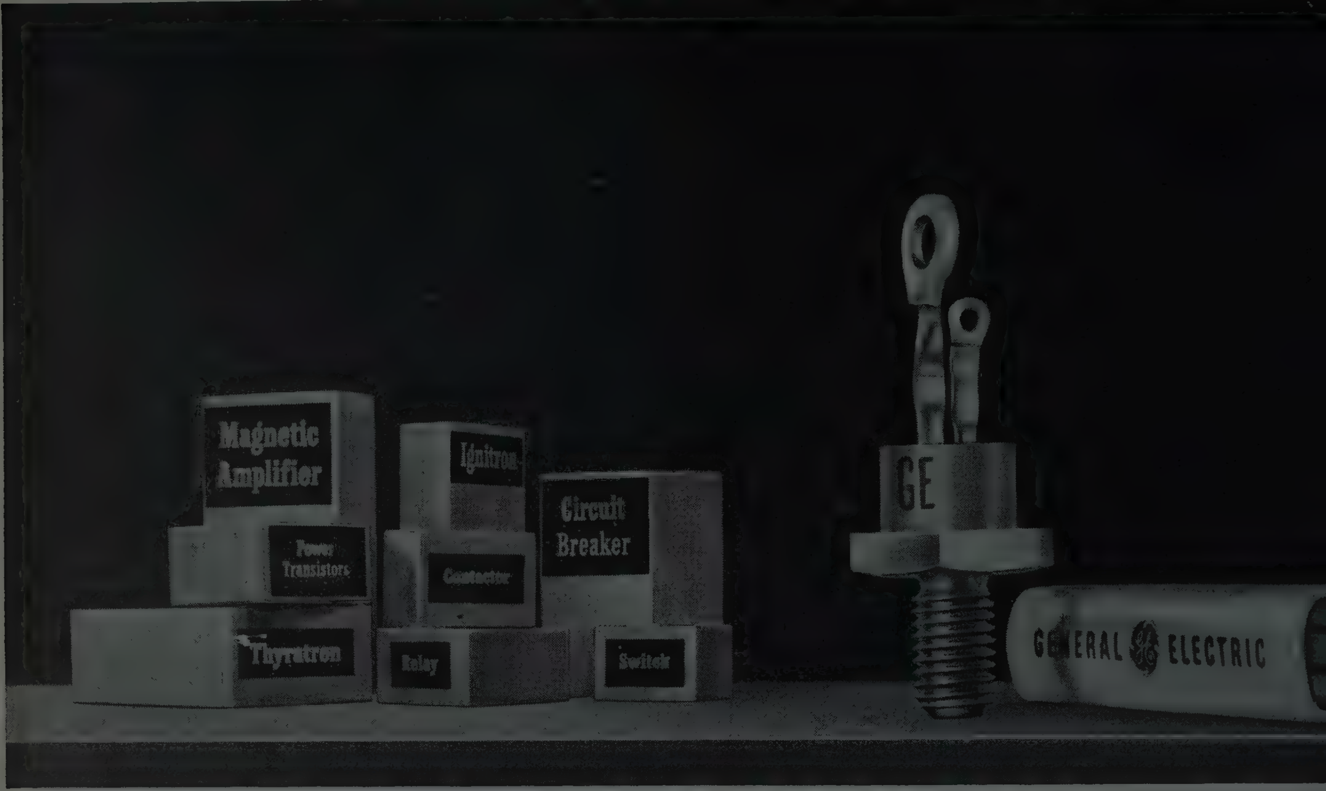
Microwave Chemicals Laboratory, Inc. also custom produces garnets to meet specific requirements.

Write for Details!

MICROWAVE
CHEMICALS LABORATORY, INC
282 SEVENTH AVENUE • NEW YORK 1, N. Y.

General Electric Semiconductor News

New controlled rectifier does all these



Maximum Allowable Ratings and Characteristics

(Resistive or Inductive Load)

	ZJ39A 25	ZJ39A 40	ZJ39A 75	ZJ39A 100	ZJ39A 150	ZJ39A 200	ZJ39A 250	ZJ39A 300
Continuous Peak Inverse Voltage (PIV)	25	40	75	100	150	200	250	300 V
Transient Peak Inverse Voltage (Non-recurrent >5 millisec)	35	60	100	150	225	300	350	400 V
RMS Voltage (Vrms)	17.5	28	53	70	105	140	175	210 V
Average Forward Current (I_F)	Up to 16 amperes							
Peak One-cycle Surge Current (i surge)	150 amperes							
Minimum Forward Breakover Voltage (V_{BO})	25	40	75	100	150	200	250	300 V
Maximum Forward Voltage (V_F Ave.)	0.75 Volts (Full Cycle Average)							
Maximum Reverse Current (I_R)	5 ma (Full Cycle Average)							
Maximum Gate Current To Fire (I_{GF})	25 ma							
Maximum Gate Voltage To Fire (V_{GF})	3 Volts							

Finer performance of G-E low-current silicon rectifie now within reach for all your requirements

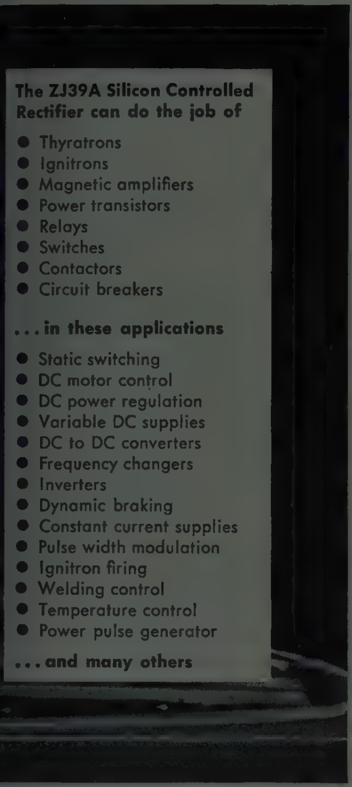
MAXIMUM RATINGS AND SPECIFICATIONS

	PIV	RMS Voltage	Cont. Reverse D-C Volt	D-C Output (150°C Amb.)	D-C Output (50°C Amb.)	One-cycle Surge Current	Full-Load Forward Voltage Drop	Leakage Current	Ambient Operating Temp.
1N536-40, 1N1095-96 series	50-600	35-420	50-600	250	750	15	0.5	0.4-0.3	165
1N440B-445B series	100-600	70-420	100-600	300-500 (100°C)	300-750	15	0.5		150-165
1N1487-92 series	100-600	70-420	100-600	250 (125°C)	750 (25°C)	15	0.55	0.3	140
1N1692-95 series	100-400	70-280	100-400	250 (100°C)	600 (50°C)	20	0.6	0.5	115
	volts	volts	volts	ma	ma	amps	volts	ma	°C

The time has come to reconsider possib plications of G.E.'s outstanding low-cu silicon rectifiers in the 1N536, 1N440 S (150°C line) . . . the 1N1487 Series (1 line) . . . and four recently added typ the 100°C area, the new 1N1692 S You'll find these devices more attracti use than ever before—both in quality price—with equally fine values in low rent silicon stacks. Stud-mounted unit also available.

General Electric low-current silicon fiers are designed for maximum forwar ductance at high operating tempera High current loads are carried *witho* ternal heat sinks. Reverse current at

obs, and more—prices reduced 50%



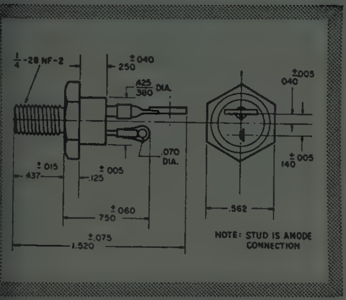
The ZJ39A Silicon Controlled Rectifier can do the job of

- Thyratrons
- Ignitrons
- Magnetic amplifiers
- Power transistors
- Relays
- Switches
- Contactors
- Circuit breakers

. . . in these applications

- Static switching
- DC motor control
- DC power regulation
- Variable DC supplies
- DC to DC converters
- Frequency changers
- Inverters
- Dynamic braking
- Constant current supplies
- Pulse width modulation
- Ignitron firing
- Welding control
- Temperature control
- Power pulse generator

. . . and many others



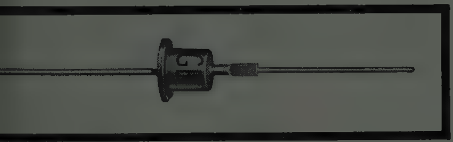
Price reductions in some cases greater than 50% will enable hundreds of new users to become acquainted with General Electric's new silicon controlled rectifier.

Neither a transistor nor a rectifier, this remarkable device combines features of both. In the reverse direction it acts like a standard rectifier. But it also blocks forward current until either a critical breakover voltage is exceeded or a signal is applied to the third lead. Then it switches to a conducting state and performs exactly like a forward-biased silicon rectifier.

The controlled rectifier offers the circuit designer current ratings comparable to thyratrons, blocking voltages useful in industrial circuits, complete control of current turn-on without complicated circuitry, and switching speeds in microseconds.

While in many ways similar to the gas thyratron, the controlled rectifier provides faster firing and recovery times, very low forward voltage drop, higher efficiency, absence of filament with attendant warm-up delay and power consumption, and higher-temperature operation.

Check the sample ratings and suggested applications at left. Application data and specifications will be sent on request.



num junction temperature is maintained at an xtremely low level, making these devices ideal for ow-leakage applications.

Minimum forward voltage drop and a hermetially sealed case have produced silicon rectifiers vhose reliability exceeds all existing MIL specs. A comparative evaluation shows that G-E devices nave the *highest* resistance to thermal runaway at naximum full load operating temperatures. Thernal shock and temperature-cycle tests show a closer natch of materials for expansion and contraction, o protect against breaking the hermetic seal and hattering the silicon pellet.

Ask your G-E semiconductor representative for he "big news" on low-current silicon rectifiers. Or vrite for more information.

For fast delivery, lower prices, see your local G-E distributor!

A recent check shows that General Electric transistors and rectifiers are being sold by local tube distributors for within pennies of the factory price on quantities less than one hundred—with the important difference that transportation charges are prepaid when you buy from your local G-E distributor.

Increased stocking of semiconductors by local G-E distributors means you now have *one* source for all your electronic needs. General Electric distributors can also furnish you with a wide variety of technical information, application data and spec sheets.

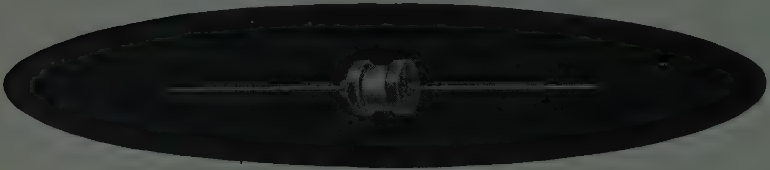
General Electric Company, Semiconductor Products Department, Section S54858, Electronics Park, Syracuse, N. Y.

GENERAL ELECTRIC

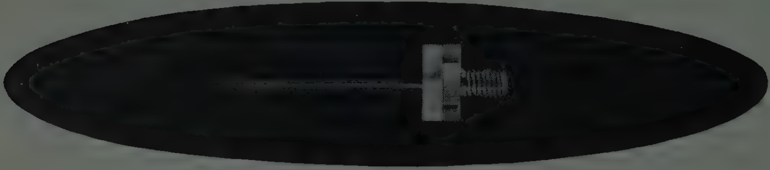
Whether you need

SILICON RECTIFIERS

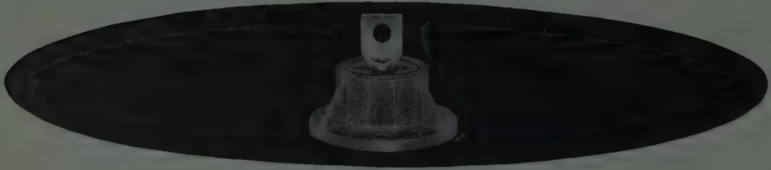
rated at 500 mils



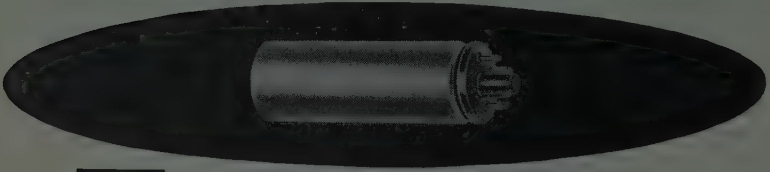
. . . or 10 amps



. . . or 200 amps



. . . or tube replacements



Tarzian Silicon Rectifiers
cover the complete range. Write for complete information
or send an outline of your requirements.

We'll see you at the Wescon— Booth 1326

SARKES TARZIAN, INC.
RECTIFIER DIVISION
DEPT. P-2, 415 N. COLLEGE AVENUE, BLOOMINGTON, INDIANA
In Canada: 700 Weston Road, Toronto 9, Telephone Rogers 2-7535
Export: Ad Auriema, Inc., New York City

BOESCH

★ *improved*
★ *faster*
★ *completely automatic*

BW2 BOBBIN *winder*
rugged, versatile, high speed winder for bobbins, solenoids, resistors, relays and other random-wound coils.

Boesch Manufacturing Co., Inc. Danbury, Conn.

Section Meetings

(Continued from page 58A)

MILWAUKEE

"Engineering Education," a panel discussion; 5/13/58.

"Scatter Propagation," R. M. Mitchell, Collins Radio; 5/20/58.

NORTHERN ALBERTA

"The Early Days of Radio," G. R. A. Rice, CFRN-Radio & CFRN-TV; 5/30/58.

NORTHWEST FLORIDA

"Eglin Gulf Test Range Planning," M. P. Brown, Hq. APGC; 5/27/58.

"The Radio Engineers Role in Research and Testing at the Air Proving Ground Center," J. K. Sun, Hq. APGC; 6/17/58.

OKLAHOMA CITY

"TV Station KWTV," a movie, M. Thomas, TV station KWTV; 5/13/58.

PHOENIX

"Designing a Precision Data Handling System," M. L. Klein, Cohu Electronics; 5/23/58.

PITTSBURGH

"The Ampex Video Tape Recorder," C. Luscombe, Ampex Corp.; 3/10/58.

PORTLAND

"Transistor Oscillators and Amplifiers," "Nuclear Power Plant Controls," "Magnetic Amplifiers," students, Oregon Colleges; 5/6/58.

"Tour of L.R.I.," S. D. Bennett, J. K. Trolan; "Development and Applications of Field Emission Cathodes," J. K. Trolan, E. E. Martin, F. J. Gundhauser; 6/7/58.

PRINCETON

Open House, RCA Research Labs.; 5/8/58.

Annual Banquet and Dance; 5/16/58.

RIO DE JANEIRO

"Cybernetics Fundamentals," H. C. deMattos, Army Eng'g. School; 1/8/58.

"Actualities and Perspectives in Scientific Research," H. Costa, Brazilian Air Force; 3/25/58.

"Electronics and Nuclear Reactors," B. Cimbleris, Nuclear Energy Commission; 4/24/58.

ROCHESTER

"The Tape Recorder as an Instrumentation Device," R. M. Olivier, Ampex Corp.; 5/22/58.

SAN ANTONIO

"Millimeter Wave Techniques," J. Douglas, Univ. of Texas; 3/19/58.

"An Analog Computer for the Study and Suppression of Pulsations in Gas Pipe Line Compressor Stations; W. Munitz, Southwest Res. Inst.; 3/20/58.

"Interference Measurements Technology," F. J. Morris, Electro-Mechanics Co.; 5/22/58.

SAN DIEGO

"Present State of Video Recording," F. Gonsales, B. F. Frankle, Ampex Corp.; 6/3/58.

SOUTH BEND-MISHAWAKA

"Tour of Facilities and Demonstration of New Equipment," B. Erickson, Heath Co.; 5/29/58.

SOUTH CAROLINA

Tour of "News and Courier," newspaper Plant; 5/19/58.

(Continued on page 64A)

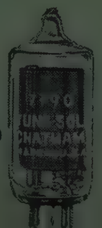
Two Type 7191's receive special "D.C. hold-off" vibration test. *All* Tung-Sol/Chatham miniature hydrogen thyratrons — 7190, 7191, 7192 — must "hold off" while subject to 15G vibration, swept from 50 to 2,000 cps in 4 minutes. Tubes also are shocked at 48° hammer angle in Navy high-impact flyweight shock machine, equal to 720G/1 millisecond shock.

Tung-Sol/Chatham miniature hydrogen thyratrons supply test-proved ruggedness for missile use!

Extensive in-factory tests assure designers Tung-Sol/Chatham miniature hydrogen thyratrons — 7190, 7191, 7192 — can withstand the severe shock and vibration met in missile flight. Performance of these tubes in several operational missiles gives in-use proof of their ruggedness.

In radar modulators and tracking beacons, these compact tough tubes supply 10 KW, replace bulkier types. Broad range of pulse repetition rates widens design choice . . . zero bias simplifies circuitry and triggering requirements. Tubes hold off high voltage, pass high peak current with low tube voltage drop. Three types available: 7190 — pin base, 7191 — top anode connector, 7192 — flexible leads.

Tung-Sol, only producer of miniature hydrogen thyratrons for missiles, can supply you immediately. For complete data on these types . . . on special-purpose tubes of all types, phone or write. Tung-Sol Electric Inc., Newark 4, New Jersey. Commercial Engineering Offices: Bloomfield and Livingston, New Jersey; Culver City, California; Melrose Park, Illinois.



7190

7191

7192

ts TUNG-SOL®

Operate your...

- tape recorder
- P. A. system
- portable TV set
- hand tools

FROM YOUR CAR, Boat or Plane!

with ATR

INVERTERS

FOR CHANGING YOUR STORAGE BATTERY CURRENT TO

A.C. HOUSEHOLD ELECTRICITY ANYWHERE... in your own CAR, Boat or Plane!

OPERATES PORTABLE TV SET directly from your car!

OPERATES
- TAPE RECORDERS
- DICTATING MACHINES
- PUBLIC ADDRESS SYSTEMS
- ELECTRIC SHAVERS

directly from your car!

MAKE YOUR CAR, BOAT OR PLANE "A ROLLING OFFICE!"

OPERATES
- RADIOS
- RECORD PLAYERS
- MIXMASTERS, ETC.

directly from your car!

mounted out of sight under dash or in trunk compartment

ATR UNIVERSAL **INVERTERS**

Especially designed to change 6 or 12 volt D.C. to 110 volt A.C. 60 cycles.

for...
- EXECUTIVES
- POLICEMEN
- SALESMEN
- REPORTERS
- OUTDOOR MEN
- FIREMEN
- PUBLIC OFFICIALS

MODELS 6U-RHG (6 volts) 125 to 150 watts. Shipping weight 27 lbs. List price..............$89.95
DEALER NET PRICE.......$59.97
12U-RHG (12 volts) 150 to 175 watts. Shipping weight 27 lbs. List price....................$89.95
DEALER NET PRICE.......$59.97

Write for literature on other Sizes and Models of ATR INVERTERS, priced as low as $9.95 list.

SEE YOUR JOBBER OR WRITE FACTORY

✓NEW MODELS ✓NEW DESIGNS ✓NEW LITERATURE

- "A" Battery Eliminators
- DC-AC Inverters
- Auto Radio Vibrators

ATR **AMERICAN TELEVISION & RADIO Co.**
Quality Products Since 1931
SAINT PAUL 1, MINNESOTA, U. S. A.

Section Meetings

(Continued from page 62A)

TOKYO

"Television Color Tubes," W. M. James, RCA Lab.; 4/10/58.

"Review of the Philips Research Laboratories," H. Rinia, Philips Res. Lab.; 4/17/58.

General Discussions, "Section activities"; 5/3/58.

TOLEDO

"Conversion of Broadcast Transmitters to New Coaxial Tubes," C. Weeden, Machlett Labs.; "Growth of the IRE," Donald G. Fink, IRE President; 3/19/58.

"Digital Electronics for Weight Control," R. Williams, Toledo Scale Co.; 4/10/58.

TUCSON

"The Computer as a Tool in Research," A. W. Wymore, Applied Res. Lab., of Univ. of Ariz.; 3/19/58.

"Discussion of IRE affairs," Donald G. Fink, IRE President"; "The Theory of Games," a demonstration, E. D. Nering, Univ. of Ariz.; 4/21/58.

"Coupling Networks for Hard Tube Modulators and Pulse Amplifiers," T. R. O'Meara, Hughes Aircraft Research Labs.; 5/21/58.

TULSA

Annual Meeting; 5/29/58.

TWIN CITIES

"High Power VHF UHF Coaxial Transmission Lines, Wave Guides and Components," H. L. Woodbury, Andrew Corp.; 5/15/58

VANCOUVER

"Engineering in Radio Frequency Spectrum Management," W. Smith, Dept. of Transport; 3/24/58.

"Electronic Tide Simulator," a field trip, W. H. Needler, J. D. Tully, N. Fofinoff, M. Pirart, Fisheries Research Board; 4/19/58.

VIRGINIA

"An Automatic Freight Car Classification Yard," W. A. Robinson, Westinghouse Air Brake Co.; 5/23/58.

WASHINGTON

"Production of High Temperatures in Thermonuclear Research," A. C. Kolb. U. S. Naval Res. Lab.; 5/5/58.

"Optimum Balance Between Performance and Cost of Hi-Fi Components and Systems," panel, A. Preisman, CREI; I. Levine, NBS; H. P. Meisinger, G. S. McDonald, Lee Inc.; G. F. Montgomery, NBS; F. H. McIntosh; 6/2/58.

WICHITA

"Television FM Receiver Application of the Diffused Base Transistor," H. F. Cooke, Texas Instruments; 4/30/58.

SUBSECTIONS

CHARLESTON

"Instrument Landing System used at the Charleston Airport," M. E. Denman, CAA; 3/17/58.

Tour of G.E. Capacitor Plant; 4/25/58.

EASTERN NORTH CAROLINA

"Development of a High-Precision Electromechanical Linear Transducer," D. R. Cates, student, Duke Univ.; "Essentials of Radar," J. C. Barbot, North Carolina State College; 5/9/58.

(Continued on page 66A)

Watch for our unveiling on a new line of microwave oscillators

Coverage from 0.5 to 18.0 Kmc

WESCON
LOS ANGELES, CALIFORNIA
AUG. 19-22 • BOOTH NO. 938

MENLO PARK ENGINEERING
721 HAMILTON AVE. MENLO PARK, CALIFORNIA
DAvenport 6-9080

now, most flexible line of PNP Germanium Power Transistors

40 Watts*

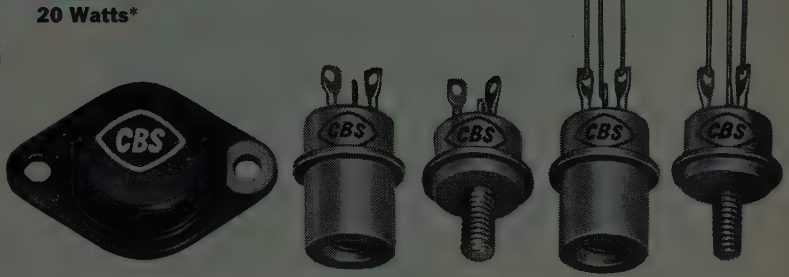
30 Watts*

20 Watts*

**Collector dissipation at 25°C with infinite heat sink.*

3 POWER GROUPS

5 PACKAGES



MORE THAN 100 TYPES

40-WATT GROUP
Types Available

Current Gain‡					Packages#
160	LT-5096	LT-5105	LT-5114	LT-5123	Diamond
	LT-5095	LT-5104	LT-5113	LT-5122	Male
	LT-5094	LT-5103	LT-5112	LT-5121	Female
80	LT-5093	LT-5102	LT-5111	LT-5120	Diamond
	LT-5092	LT-5101	LT-5110	LT-5119	Male
	LT-5091	LT-5100	LT-5109	LT-5118	Female
40	LT-5090	LT-5099	LT-5108	LT-5117	Diamond
	LT-5089	LT-5098	LT-5107	LT-5116	Male
	LT-5088	LT-5097	LT-5106	LT-5115	Female
	30V	60V	80V	100V	

Minimum Breakdown Voltage†

30-WATT GROUP
Types Available

Current Gain‡					Packages#
100	LT-5060	LT-5069	LT-5078	LT-5087	Diamond
	LT-5059	LT-5068	LT-5077	LT-5086	Male
	LT-5058	LT-5067	LT-5076	LT-5085	Female
60	LT-5057	LT-5066	LT-5075	LT-5084	Diamond
	LT-5056	LT-5065	LT-5074	LT-5083	Male
	LT-5055	LT-5064	LT-5073	LT-5082	Female
30	LT-5054	LT-5063	LT-5072	LT-5081	Diamond
	LT-5053	LT-5062	LT-5071	LT-5080	Male
	LT-5052	LT-5061	LT-5070	LT-5079	Female
	30V	60V	80V	100V	

Minimum Breakdown Voltage†

20-WATT GROUP
Types Available

Current Gain‡					Packages#
60	LT-5028	LT-5034	LT-5042	LT-5051	Diamond
	LT-5027	LT-5033	LT-5041	LT-5050	Male
	LT-5026	LT-5032	LT-5040	LT-5049	Female
40	LT-5025	LT-5031	LT-5039	LT-5048	Diamond
	LT-5024	LT-5030	LT-5038	LT-5047	Male
	LT-5023	LT-5029	LT-5037	LT-5046	Female
20	LT-5022	2N157	2N157A	LT-5045	Diamond
	LT-5021	LT-55	LT-5036	LT-5044	Male
	2N156	2N158	LT-5035	LT-5043	Female
	30V	60V	100V	**120V**	

Minimum Breakdown Voltage†

‡Minimum large-signal current gain: 40-watt group at 1.0 A, 30-watt group at 0.75 A, 20-watt group at 0.50 A.

†Minimum breakdown voltage, collector to base with emitter open.

#Five packages: diamond, female industrial with solder lugs or flying leads, and male industrial with solder lugs or flying leads.

Reliable products through
Advanced-Engineering

CBS semiconductors®

CBS-HYTRON, Semiconductor Operations, Lowell, Mass.
A Division of Columbia Broadcasting System, Inc.
Sales Offices: *Newark, N. J.; Melrose Park, Ill.; Los Angeles, Calif.*

Whatever your needs in PNP germanium power transistors, CBS-Hytron can supply them: In a choice of three sizes of collector dissipations . . . 20, 30 or 40 watts. In a choice of five packages . . . diamond, female industrial with solder lugs or flying leads, and male industrial with solder lugs or flying leads. And in 36 choices of collector-to-base voltages and large-signal current gains.

See tables for types available. Write today for Bulletin E-288 giving complete data on EIA, military and special types in the widest range of current gains, collector voltages and currents available. Let the unsurpassed flexibility and width of this CBS-Hytron line help solve your individual power transistor problems.

A.C. VOLTS
DECIBELS
BALLANTINE LABORATORIES

Low noise level
Wide frequency response
High input impedance

MODEL 310A
Price $235

...with this BALLANTINE
Sensitive Electronic Voltmeter

To measure	40 microvolts to 100 volts
from	10 cycles to 2 megacycles
with accuracy (>100 μv)	3% to 1 mc; 5% above
Shorted input noise	less than 20 microvolts
Input impedance	2 megohms shunted by 19 mmfd below 10 mv; and by 9 mmfd above

Usable as null detector sensitive to 10 μv from 5 cps to 4 mc

NOTE THE MANY USES OF THIS BALLANTINE VOLTMETER:

- Acoustic measurements
- Low level vibration measurements
- Audio amplifier tests
- Carrier telephone transmission
- Ultrasonic development
- AM broadcast band signal measurements

Write for catalog for more information about this and other BALLANTINE voltmeters, amplifiers, and accessories.

BALLANTINE LABORATORIES, INC.
102 Fanny Road, Boonton, New Jersey

Section Meetings

(Continued from page 64A)

LEHIGH VALLEY

"Instrumentation and Control for a Nuclear Power Plant," A. R. Jones, Westinghouse Electric Co.; 5/21/58.

NASHVILLE

"Nike—An Anti-Aircraft Guided Missile," M. L. Fox, Western Electric Co.; 4/9/58.

"Current Techniques in Transistor Circuit Design," R. L. Weber, Texas Instruments, Inc.; 5/21/58.

NEW HAMPSHIRE

"Silicon Power Transistors," A. F. Dixon, Transitron, Inc.; 4/17/58.

NORTHERN VERMONT

"Single Sideband and Applications of S.S.," E. Martin, Collins Radio Co.; 5/19/58.

ORANGE BELT

"Welcome," F. S. Atchison, NOLC; Polaris," J. F. Mullen, Lockheed Missile Systems Div.; 5/16/58.

PALO ALTO

"The Persistor Memory Element," E. C. Crittenden, U. S. Naval Post Grad. School; 5/23/58.

PANAMA CITY

"Some Analogies in the Propagation of Radio in Air and Sound in the Sea," R. J. Urick, U. S. Navy Mine Defense Lab.; 5/27/58.

PASADENA

"Poles and Zeros," J. L. Stewart, Univ. of Southern Calif.; 5/20/58.

RICHLAND

"The Advantages of Continuous Analyzers in a Pilot Plant," C. L. Pleasance, Gen. Electric Co.; 4/4/58.

SANTA BARBARA

"Noise Sources in Communications Systems," A. J. Hannum, Hughes Aircraft Co.; "Russian Electronics," F. S. Atchison, U. S. Naval Ordnance Lab.; 6/6/58.

Professional Group Meetings

ANTENNAS & PROPAGATION

Akron—May 20

"Game Theory," Foster Brooks, Kent State Univ.

Los Angeles—May 8

"The City Hall—UCLA 36,000 MC-Link," R. C. Mackey, Univ. of California; "Propagation at 36,000 MC in the Los Angeles Basin," Warren Flock, Univ. of California.

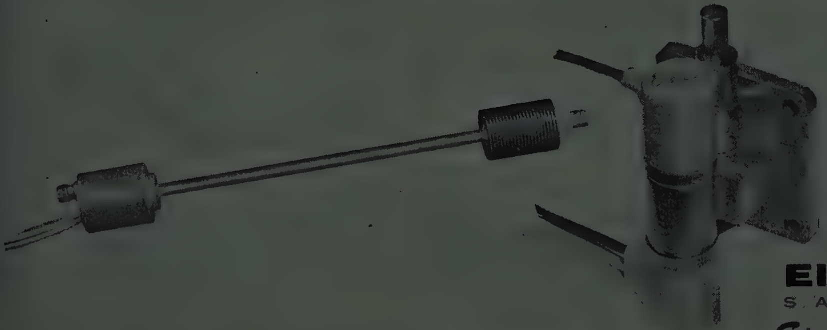
(Continued on page 70A)

Eimac
4CX1000A
4CX250B
MADE IN U.S.A.
4CX300A
MADE IN U.S.A.
EIMAC
FIRST

Covering the Spectrum with Reliable Ceramic Tubes

From audio into super high frequencies, Eimac covers the RF spectrum with modern ceramic tubes. This incomparable ceramic electron tube family— more than one-third of the Eimac line — includes reflex and amplifier klystrons, negative grid tubes, rectifiers, pulse modulators, receiving tubes, and traveling wave tubes. The tubes illustrated are typical of more than 40 Eimac ceramic tube types that are being selected by leading equipment manufacturers for use in all types of applications — from tropo-scatter to industrial heating, from single sideband to pulse.

Visit the Eimac booths, 1230-31 and 1234-35, at WESCON, August 19 to 22, in Los Angeles. Operate the unique demonstrator which hammers impact shocks upon a live Eimac ceramic tube — and prove to yourself the superiority of ceramics in electron tubes.



Eimac®

EITEL-McCULLOUGH, INC.
SAN BRUNO CALIFORNIA

Eimac First with ceramic tubes that can take it

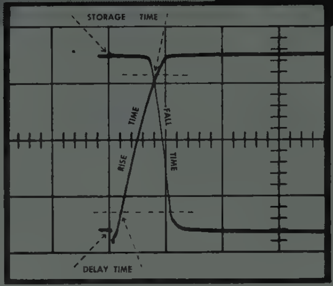
PRODUCTS DESIGNED AND MANUFACTURED BY EIMAC
Negative Grid Tubes
Reflex and Amplifier Klystrons
Ceramic Receiving Tubes
Traveling Wave Tubes
Vacuum Tube Accessories
Vacuum Switches
Vacuum Pumps

Includes the most extensive line of ceramic electron tubes

NEW PLUG-IN UNIT

for Measuring Transistor High-Frequency Characteristics by the Pulse-Response Method

The Type 53/54R Unit can trigger the Oscilloscope sweep either on the start of the test pulse only, or on both the start and finish to display delay, rise, storage, and fall times simultaneously.



The Type 53/54R Unit and your Tektronix Oscilloscope with the Plug-In Feature equip you to measure transistor delay, rise, storage, and fall times. No other equipment is needed. Just plug in the Type 53/54R Unit and you're ready to go.

CHARACTERISTICS

Collector Supply
1 to 15 v continuously variable, positive or negative. Current Capability, 400 ma.

Mercury-Switch Pulse Generator
Risetime less than 0.005 μsec. Overall risetimes with the oscilloscopes are as follows:

Types 541, 543, 545—0.012 μsec
Type 551—0.014 μsec
Type 533—0.023 sec
Types 531, 535, 536—0.035 μsec
Type 532—0.07 μsec (The Type 532 and Type 536 have an additional limitation in the lack of signal delay in the main vertical amplifier).

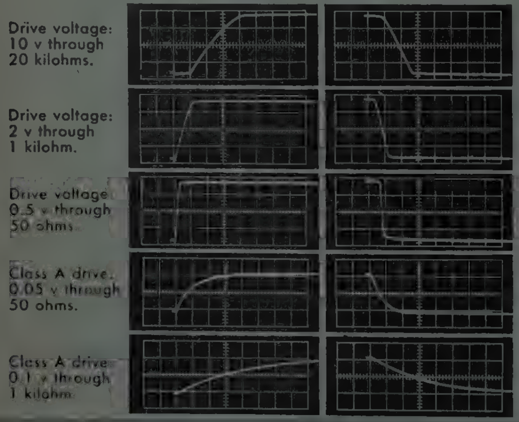
Amplitude—0.02 v to 10 v, continuously adjustable, across 50 ohms. Eight calibrated steps—0.05, 0.1, 0.2, 0.5, 1, 2, 5, and 10 v.

Bias Supply
−0.5 v to +0.5 v and −5 v to +5 v, continuously variable. Current Capability—±100 ma.

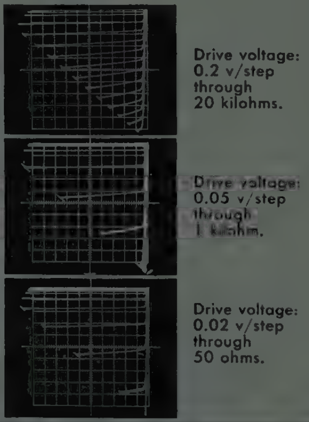
Calibrated Vertical Deflection
0.5, 1, 2, 5, 10, 20, 50, and 100 ma/cm collector current.

Price—$300 f.o.b. factory

High-frequency characteristics of a transistor under five different conditions of drive. In each pair, the photograph at left shows delay time and rise time, the start of the driving pulse coinciding with the 2-cm graticule line. The second photograph of each pair shows storage time and fall time, the end of the pulse coinciding with the 2-cm line. The Type 53/54R Unit plugged into a Tektronix Type 543 Oscilloscope — 3.5-v collector supply, 500-ohm collector load, 2-ma/div vertical calibration, 0.5-μsec/div sweep rate. Driving conditions at left of each pair.



Low-frequency characteristics of the same transistor under driving conditions paralleling those of the first three pairs at left. Family of curves photographed on a Tektronix Type 575 Transistor-Curve Tracer—0.5-v/div horizontal calibration, 1-ma/div vertical calibration, 500-ohm load line. Driving conditions at right of each photograph.



Tektronix, Inc.

P. O. Box 831 • Portland 7, Oregon
Phone CYpress 2-2611 • TWX-PD 311 • Cable: TEKTRONIX

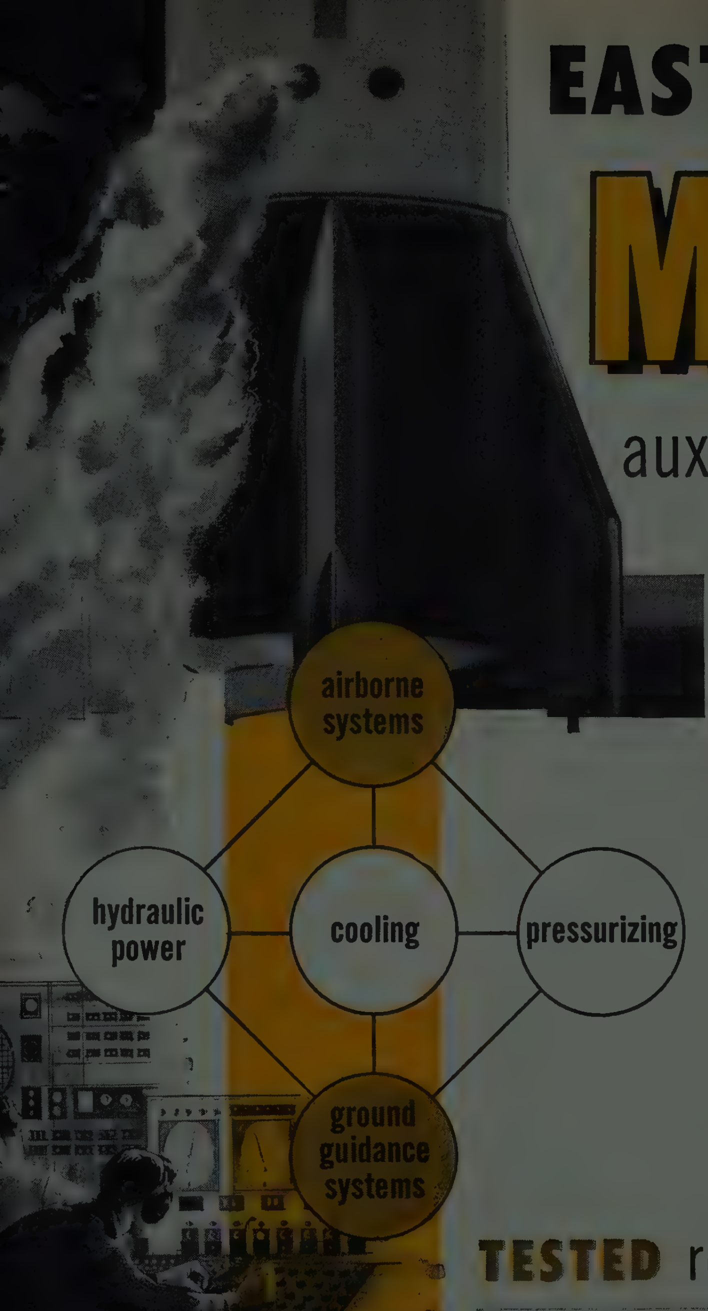
TEKTRONIX FIELD OFFICES: Albertson, L. I., N.Y. • Albuquerque • Bronxville, N.Y. • Buffalo Cleveland • Dallas • Dayton • Elmwood Park, Ill. • Endwell, N.Y. • Houston • Lathrup Village, Mich. • East Los Angeles • West Los Angeles • Minneapolis • Mission, Kansas • Newtonville, Mass. • Palo Alto, Calif. • Philadelphia • Phoenix • San Diego • Syracuse • Towson, Md. Union, N. J. • Willowdale, Ont.

TEKTRONIX ENGINEERING REPRESENTATIVES: Arthur Lynch & Assoc., Ft. Myers, Fla., Gainesville, Fla.; Bivins & Caldwell, Atlanta, Ga., High Point, N. C.; Hawthorne Electronics, Portland, Ore., Seattle, Wash.; Hytronic Measurements, Denver, Colo.

Tektronix is represented in 20 overseas countries by qualified engineering organizations.

Please call your Tektronix Field Engineer or Representative for complete specifications and, if desired, to arrange for a demonstration at your convenience.

ENGINEERS—interested in furthering the advancement of the oscilloscope? We have openings for men with creative design ability. Please write Richard Ropiequet, Vice President, Engineering.



EASTERN . . . pioneer in MISSILE auxiliary power subsystems

Eastern has developed miniature, high-output units that give reliable performance in missile auxiliary power systems. Coordination with developers at the planning stage permits Eastern continually to engineer lower weight units that allow more fuel load for longer flight duration. Eastern's experience as pioneers of the thermal frontier provides the all-important knowledge to solve temperature problems at each stage of missile development.

HYDRAULIC POWER UNITS

Miniature high-speed gear pumps are powered by aircraft motors up to 24,000 R.P.M., or direct-driven by the turbine with little or no reduction gearing needed. Missile design engineers get maximum flexibility, reliability, and simplicity with separate hydraulic systems. Eastern has produced power packs with capacity to 1.5 G.P.M. at pressure to 2,500 P.S.I. Units are completely sealed and have pressurized sumps for operation at any altitude and attitude.

ELECTRONIC TUBE COOLING UNITS

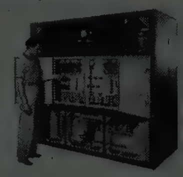
Liquid cooling of heat-producing electronic equipment is an efficient, reliable control of temperatures within safe operating limits. By creating designs based on pioneering experience, Eastern provides compact, lightweight equipment for up-to-the-minute missile needs that meet military requirements.

Cooling units have 50 to 50,000 watts dissipation rates, and refrigeration-type cooling units are furnished from 100 to 6,000 watts. Come to the **leader in the field** for complete and creative engineering help.

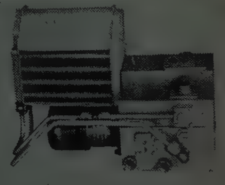
EASTERN PRESSURIZATION UNITS

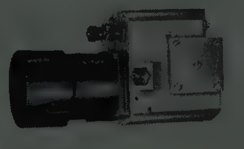
Vital electronic systems that depend on a supply of precisely controlled dry pressurized air are protected by these units. A continuing program of research and development on compressors, dehydrators, and air control systems insures that your Eastern pressurization unit features the very latest advances in this field for compactness, high temperature resistance, and reliability. They are custom-made to your special needs and meet rigid military specifications.

TESTED reliability in auxiliary power

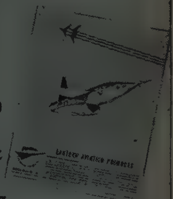

Pressurizing-dehydrating unit used in tracking and guidance system of ground-based missile controls.

High-speed gear pump provides hydraulic power to missile as integral part of APU system.


Cools high-powered electronic tubes in guidance sections of missiles.


Eastern power-pack gives hydraulic power for missile elevons and wing-folding actuators.

Maintains sensitive reference component within exact temperature limits. Dissipates 350 watts by "boiling off" water in supply tank.


NEW AVIATION BULLETIN 350 Brand new edition gives data on latest developments in hydraulic power, cooling pressurization. Send for copy today.

Eastern AVIATION PRODUCTS®

EASTERN INDUSTRIES, INC.

100 SKIFF STREET, HAMDEN 14, CONN. • West Coast Branch Office: 1608 Centinela Avenue, Inglewood 3, Calif.

TUBE PRODUCTION IS A SCIENCE AT VARIAN

Beyond the call of duty

To assure top quality in **every** Varian Tube, each must pass three separate and exhaustive series of tests before it passes final inspection. First, all electrical characteristics are checked. Next, the tube is tested under a severe vibration environment to be sure that it is particle free. After a holding period all electrical characteristics are rechecked. Only then, when **every** parameter has exceeded specifications, has the tube met Varian's high measure of perfection.

This is typical of the care involved in the manufacture of Varian tubes . . . and one of the reasons why they are considered the standard of the industry. Over 100 of these tubes are described and illustrated in our latest catalog. Write for your copy today.

VA-2018

THE MARK OF LEADERSHIP

VARIAN associates

PALO ALTO 2, CALIFORNIA

Representatives thruout the world

KLYSTRONS, TRAVELING WAVE TUBES, BACKWARD WAVE OSCILLATORS, HIGH VACUUM PUMPS, LINEAR ACCELERATORS, MICROWAVE SYSTEM COMPONENTS, R.F. SPECTROMETERS, MAGNETS, MAGNETOMETERS, STALOS, POWER AMPLIFIERS, GRAPHIC RECORDERS, RESEARCH AND DEVELOPMENT SERVICES

Professional Group Meetings

(Continued from page 66A)

AUDIO

Baltimore—April 17

"Transistorized Audio Amplifier," John Tewksbury, Bendix Radio; "Design of a Horn-Loaded Speaker Enclosure," John Markwalter, Aircraft Armaments.

Dayton—April 3

"A Review of Current High Intensity Sound System Developments," R. E. Liebich, Stromberg-Carlson.

Philadelphia—May 14

"Stereo-Panoramic Sound Reproduction," John Volkmann, RCA.

San Francisco—March 11

"Panel Discussion: Musical Reproduction—Viewpoints," Ross Snyder, Moderator, Ampex Corp., B. N. Oliver, Hewlett Packard, R. A. Long, Stanford Research Inst., Leonard Ratner, Stanford Univ., Leonard Tressel, San Francisco Symphony and Ampex Corp.

Washington—June 2

"Optimum Balance Between Performance and Costs of High Fidelity Components," Franklin Montgomery, Peter Meisinger, Frank McIntosh, Jerry McDonald, Irving Levine, and Al Preisman.

Washington—April 1

"Design Characteristics of a New FM Tuner," Gordon Gow, McIntosh Lab.

AUDIO, BROADCAST TRANSMISSION SYSTEMS

Boston—May 15

"Westrex Stereodisk," E. A. Dickinson, Westrex Corp.

AUTOMATIC CONTROL

Long Island—March 11

"Adaptive Control Systems," J. G. Truxal, Polytechnic Institute of Brooklyn.

BROADCAST & TELEVISION RECEIVERS

Los Angeles—May 22

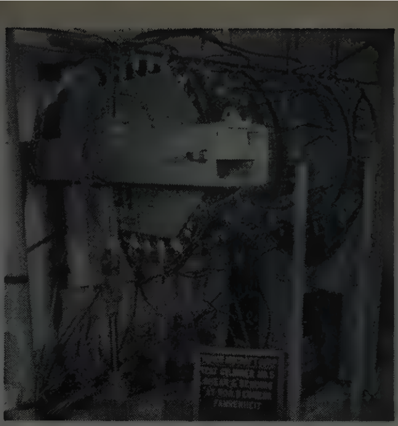
"Commercial Applications of Transistors," H. V. Stewart, Texas Instrument Co.

BROADCAST TRANSMISSION SYSTEMS

Philadelphia—May 22

"F.M. Multiplexing," E. J. Meehan, WCAU Philadelphia Bulletin; "Color Video Tape Recording," J. Greever, RCA.

(Continued on page 73A)



Temco AIRCRAFT DALLAS

CAN PUT HI-TEMPERATURE STRUCTURES INTO YOUR PRODUCTION

When Temco engineered and developed the aft-fuselage and vertical stabilizer section of Convair's B-58 Hustler . . . the wing section and fuselage panels of Temco's own TT-1 jet trainer . . . the wings of the air-launched "Teal" missile . . . the aircraft industry acknowledged Temco as a leader in development and production of honeycomb sandwich and hi-temperature structures. Missile applications currently programmed are substantial recognition of Temco's stature.

At Temco metal and plastic sandwich structures have been employed in all types of airframe applications, with notable development in the field of stronger, higher heat-resistant metal bondings . . . in improved plastic materials and methods of reinforced plastic honeycomb fabrications.

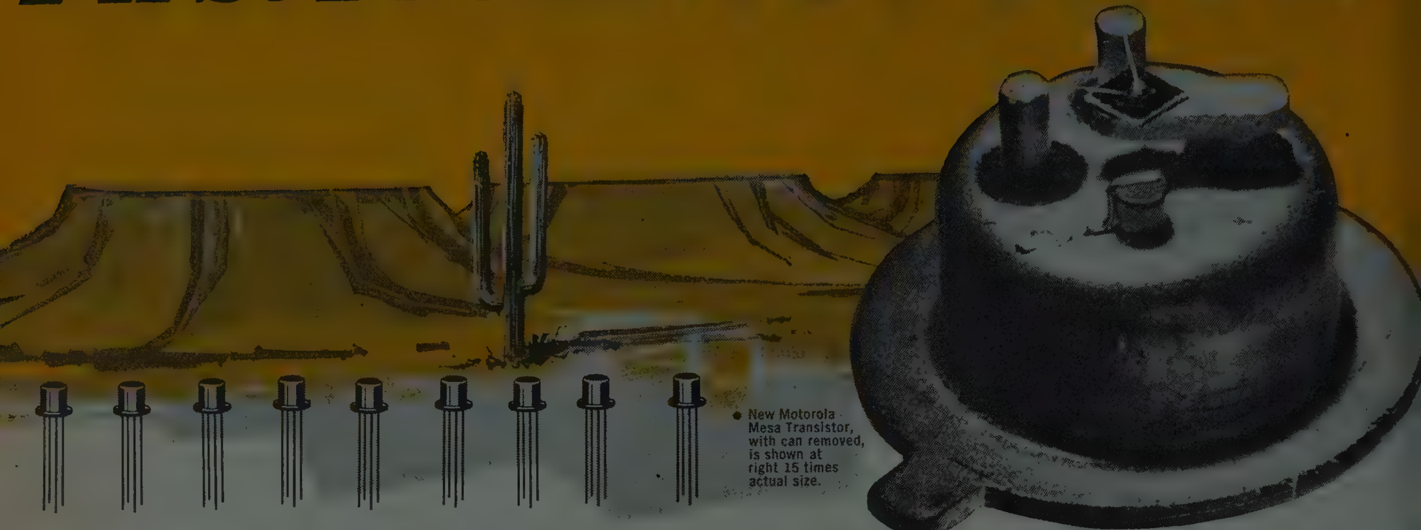
Other outstanding advances now under development at Temco are a new low-cost process for brazing stainless steel honeycomb structures, employing a revolutionary new concept . . . and experimental progress in the new field of "cermets."

Since pioneering the "total package" concept of subcontracting . . . design, tooling and production . . . Temco's engineering staff and facilities have increased significantly, a growth as rapid and as sound as that of the industry they serve. Today these design support capabilities have been extended to encompass complete systems management. **Whether your need is for a component, a subassembly, or a subsystem, an inspection of Temco capabilities will prove profitable.**

YOUR
INQUIRY IS
OUR CHALLENGE
AT . .

TEMCO ®
AIRCRAFT CORPORATION • DALLAS, TEXAS

First From MOTOROL


New Motorola Mesa Transistor, with can removed, is shown at right 15 times actual size.

UHF MESA TRANSISTOR

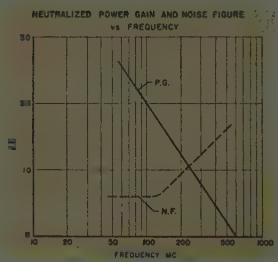
2N700 LOW-NOISE HIGH-FREQUENCY AMPLIFIER

TYPICAL CHARACTERISTICS

TYPE	*f max*	*Power Gain*	BV_{CB} @ 100μa	*NF* @ 200 *mcs*	*Max Power*
2N700	600 mcs	12 db @ 200 mcs	33 volts	9 db	50 mw

actual size

Operating Temperature
100°C case temperature with
12 mw dissipation
Germanium PNP

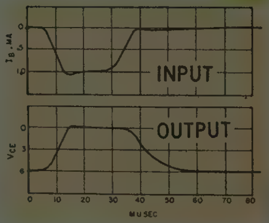


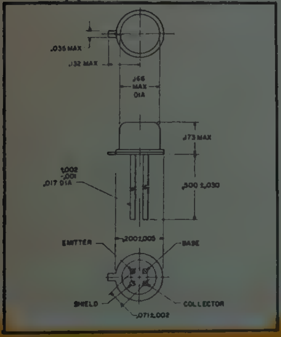
2N695 ULTRA HIGH-SPEED SWITCH

TYPICAL CHARACTERISTICS

TYPE	BV_{CB}	I_{CO} @ 5 *volts*	β *sat.* at 20 *ma*	I_C *max*	P_C
2N695	20 volts	.8μa	30	20 ma	50 mw

Operating Temperature
100°C case temperature with
12 mw dissipation
Switching Times
in the order of 10 mμsec
Germanium PNP





the beginning of an exciting new transistor family

- Extreme reliability — only high temperature materials used, process carefully controlled.
- Higher operating temperatures.
- Rugged — withstands 50,000G acceleration.
- New header design provides effective interelectrode capacitance isolation . . . smaller inductance.
- Low nuclear radiation susceptibility.
- Modified JETEC 20 case . . . hermetically sealed.
- Meets or exceeds mechanical and environmental requirements of MIL-T-19500A.
- High uniformity — "Normal" instead of "selected" distribution.
- **A Revolutionary New Family**
  These are only the first of a wide variety of germanium Motorola Mesa Transistors coming your way soon.

FOR COMPLETE TECHNICAL INFORMATION
concerning Motorola Mesa Transistors
contact the nearest Motorola regional office;
or wire, write or phone
MOTOROLA, INC.,
5005 East McDowell Road, Phoenix, Ariz.
BRidge 5-4411 Teletype PX80.

"DEPENDABLE QUALITY—IN QUANTITY"

MOTOROLA SEMICONDUCTORS

MOTOROLA, INC.
5005 E. McDOWELL
PHOENIX, ARIZONA

ON DISPLAY AT WESCON | BOOTH 628-9

REGIONAL OFFICES

RIDGEFIELD, NEW JERSEY
540 Bergen Boulevard
WHitney 5-7500

CHICAGO 44, ILLINOIS
4900 West Flournoy Street
ESterbrook 9-5200

HOLLYWOOD 28, CALIFORNIA
6555 Sunset Boulevard
HOllywood 5-3250

Professional Group Meetings

(*Continued from page 70A*)

Washington—May 28

An informal description of the WRC-TV studio and plant design was presented by John Rogers, Engineer in Charge, National Broadcasting Company, Washington, D. C. prior to a tour of the studios and transmitting facilities.

CIRCUIT THEORY

Los Angeles—May 13

"Review of Adaptive Systems," J. A. Aseltine, Aeronutronic Systems Inc.; "Properties of Junction Transistor Tetrodes," D. W. Boensel, Jet Propulsion Lab.

Montreal—May 14

"Geometrical Determination of Scattering Matrix of a Junction of N Waveguide," Raymond Vaillancourt, Defense Research Board.

San Antonio—May 21

"Interference Measurements Circuitry," Fred Morris, Electro-Mechanics Co.

COMMUNICATIONS SYSTEMS

Philadelphia—May 20

"Sea-Going Wireless Comes of Age," A. F. Miller, Atlantic Refining Co.

San Francisco—May 27

"Transmitter, Receiver and Antenna Equipment," K. E. Breymayer, Lenkurt Electric Co.; "High Power Vacuum Tubes," G. M. W. Badger, Eitel-McCullough; "Power Amplifiers," B. E. Nelson, Varian Associates.

San Francisco—May 13

"Propagation Aspects of Scatter Communications," A. T. Waterman, Jr., Stanford University.

COMPONENT PARTS

Baltimore—May 27

"The Components Engineer & The Sales Engineer, Equipment Design & Reliability Consultants," P. C. Knox, East Coast Liaison, Inc.; "A Preview of Developments in Solid State Electronics," F. E. Wenger, ARDC.

Baltimore—April 22

"Application of Thermal Relays," David Marks, G-V Controls Inc.

Dayton—April 18

Tour of the facilities of the Dayton Power and Light Co.

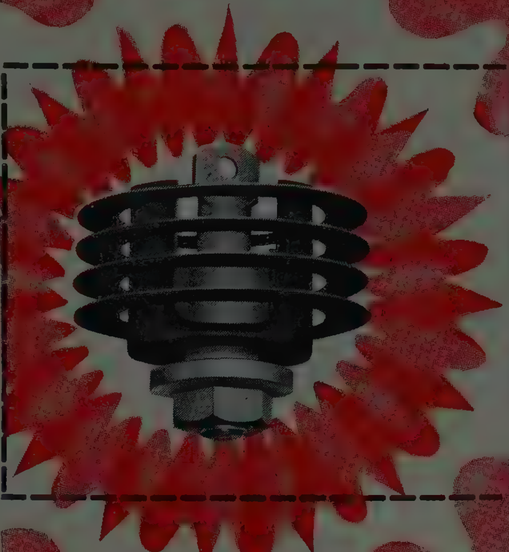
Los Angeles—May 26

"Discussion of Design Problems Associated with Quartz Crystals for Frequency Control," H. E. Blasier, Monitor Products Co.

(*Continued on page 78A*)

Build RELIABILITY into every circuit

FOR TUBES
TRANSISTORS
COMPONENTS



specify
BIRTCHER
cooling
and/or
retention
devices

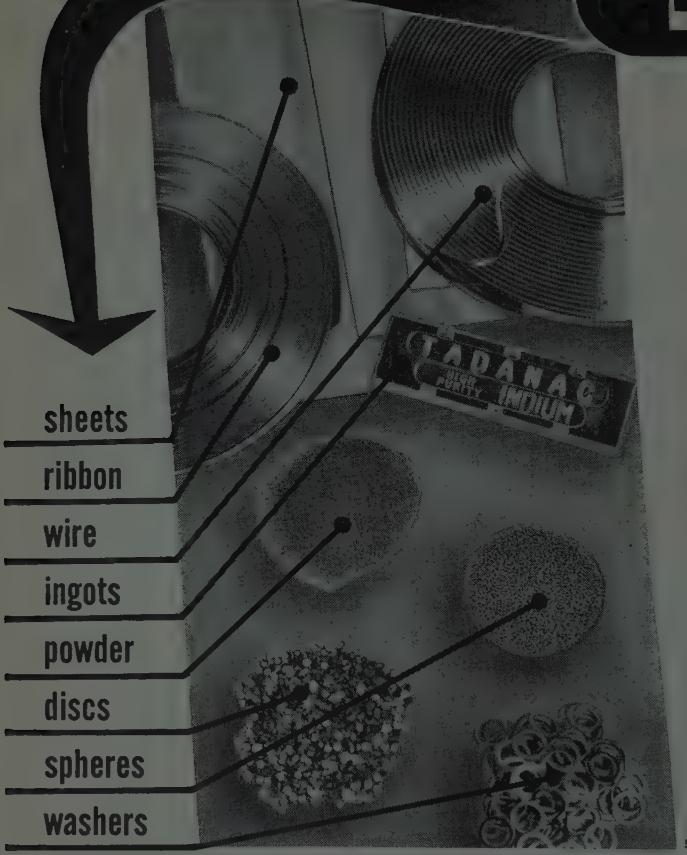
the new Birtcher Diode Radiator is shown actual size

85% of all equipment failures can be directly traced to tube or component failure caused by heat and/or vibration. Birtcher engineers are currently solving tough reliability problems in military and civilian equipment through the application of more than 8,000 designs of cooling and retention devices... specially adapted or redesigned where necessary.

THE BIRTCHER
CORPORATION
4371 Valley Blvd., Los Angeles 32, California

INDUSTRIAL DIVISION

For catalogs or special design information write direct or contact your local Birtcher Sales Engineering Representative.



"INDIUM"

and High Purity Metals...

As one of the world's largest primary producers, we are supplying TADANAC Brand Indium and Indium Alloys to leading American, European and Canadian electronic firms. We are in quantity production of the forms shown and are prepared to preform and alloy to your specifications. Our prices include customs duties and we handle all customs procedures. Our Technical Service Department, backed by the full facilities of our Research Division, is ready to assist you in the use of this versatile metal, available as

TADANAC High Purity Indium—99.999% (by diff.)
TADANAC Standard Grade Indium—99.97+%
TADANAC Indium Alloys—a wide range to customer specifications

Other **TADANAC** High Purity Metals
We can supply **LEAD, CADMIUM, SILVER** or **BISMUTH** with a total impurity content of less than 1 p.p.m.* or **ZINC** with a total impurity content of less than 2 p.p.m.*
* Total impurity content determined by spectrographic analysis

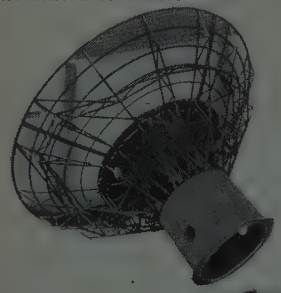
For further information and a new booklet on Indium Properties and Uses write:

COMINCO
The Consolidated Mining and Smelting Company of Canada Limited
METAL SALES DIVISION
215 St. James Street. W. Montreal 1, Quebec, Canada

57164 ME

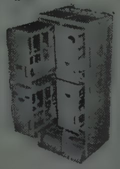
ANTENNAS

Circular and rectangular parabolic antennas with reflector tolerances to meet the most rigid specifications . . . fabricated to order.



CABINETS

Precision construction to your exact specification of cabinets and consoles for electronic equipment.



Consult our Engineering Staff in predesigning or development stages of any project at *No Obligation!*

WASHINGTON ALUMINUM COMPANY, INC.

Dept. 26-8
Baltimore
29, Md.
Phone
Circle
2-1000

W.A.C.O.®

Consultant Engineers

Contract Engineers
Senior and Associate Engineers
EEs, MEs, IEs, Physicists: B.S., M.S., or Ph.D.'s

- PROPOSALS AND ESTIMATING
- FEASIBILITY STUDIES
- RESEARCH AND DEVELOPMENT
- FIELD ENGINEERING
- PRODUCTION ENGINEERING

"Serving Electronics to Military and Industry"
EXPANDING SIX DIVISIONS THROUGHOUT THE U.S.A.

Continental Consultants, Inc.

703 BERNLEY BLDG., PHILADELPHIA 7, PA. ■ Rittenhouse 6-6669

Address Inquiries to:

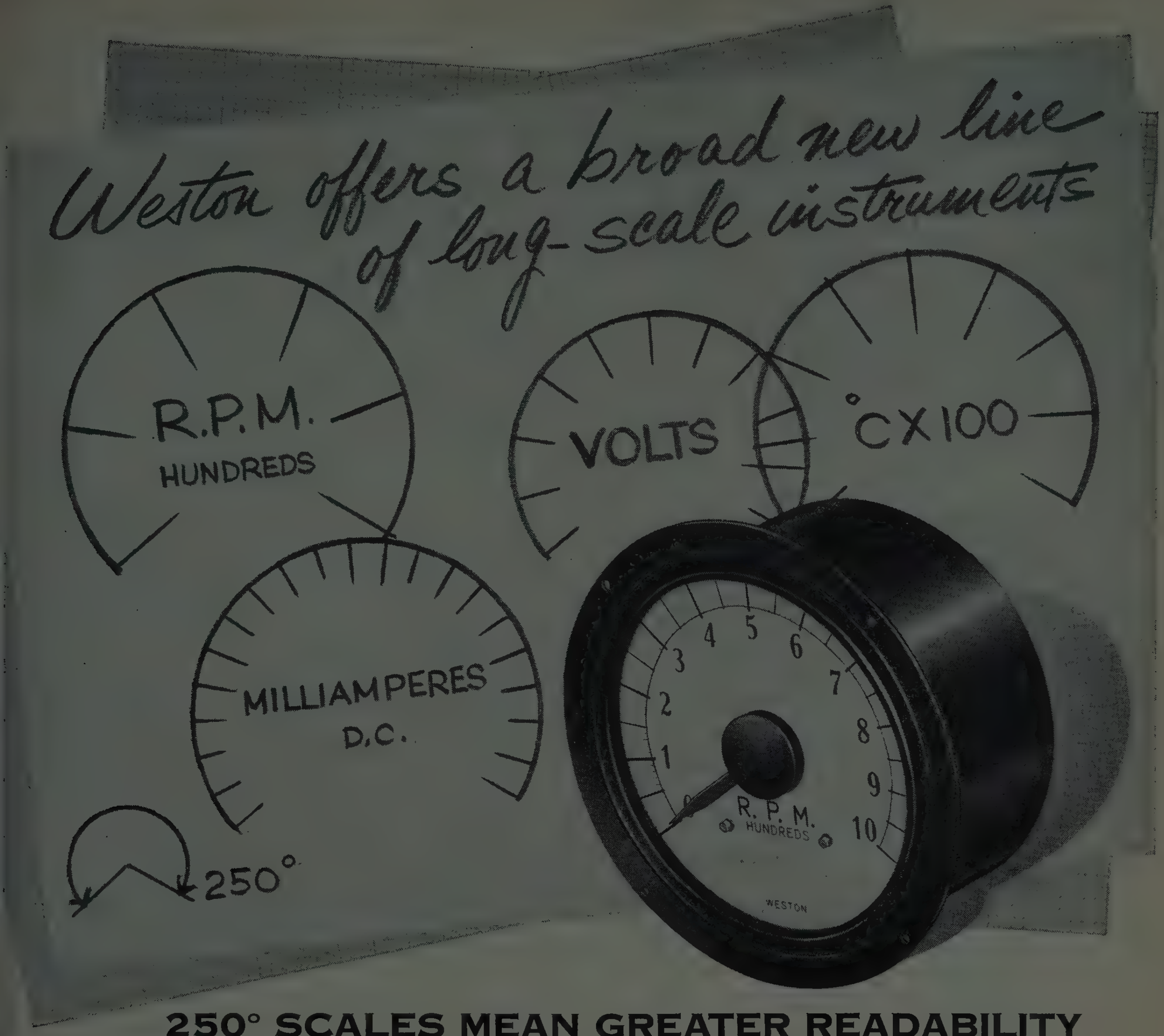
SECRETARY
ALUMNI ASSOCIATION
CAPITOL RADIO
ENGINEERING INSTITUTE
ECPD Accredited Technical Institute Curricula
3224-16th ST. N.W.
WASHINGTON 10, D.C.

Attention!

CREI ALUMNI

Students, former students and graduates of both the CREI Home Study Course and the Residence School are invited to join the CREI Alumni Association. Write us, we'll put you in touch with the nearest Local Chapter of the Association. If there isn't one near you, we'll give you names of other Alumni in your area and tell you how you can start a chapter. Write to the Executive Secretary, CREI Alumni Association for full particulars. If you are not receiving the Alumni quarterly report or the Monthly CREI Times send us your name and address. We'll be glad to add your name (Mention the "Proceedings of IRE").

WESTON INSTRUMENTS: STANDARDS OF STABILITY IN SCIENCE AND INDUSTRY


Weston offers a broad new line of long-scale instruments
R.P.M.
HUNDREDS
VOLTS
°C X 100
MILLIAMPERES
D.C.
250°
0
1
2
3
4
5
6
7
8
9
10
R.P.M.
HUNDREDS
WESTON

250° SCALES MEAN GREATER READABILITY FROM EACH SQUARE INCH OF PANEL SPACE

Weston's new series of Long-Scale Instruments now fills the requirements of a wide variety of special applications. Rugged, spring-backed-jewel mechanisms are self-shielded for immunity to the effects of stray magnetic fields. The instruments may be mounted without concern for panel thickness or material. Thus, exceptional stability (both mechanical and electrical) teams up with unequalled readability for a new high in panel instrument value. Accuracies are within ±1% of full-scale range.

Weston Long-Scale Instruments are available in Aircraft and Standard Flanged cases for a wide range of current, voltage, tachometric and temperature indications. Consult your local Weston representative for complete details on Long-Scale Instruments . . . or write for Catalog A-50. Address: Weston Instruments, Division of Daystrom, Inc., Newark 12, N. J. *In Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 10, Ont. Export: Daystrom Int'l., 100 Empire St., Newark 12, N. J.*

Take advantage of Weston's unusually fast prototype service!

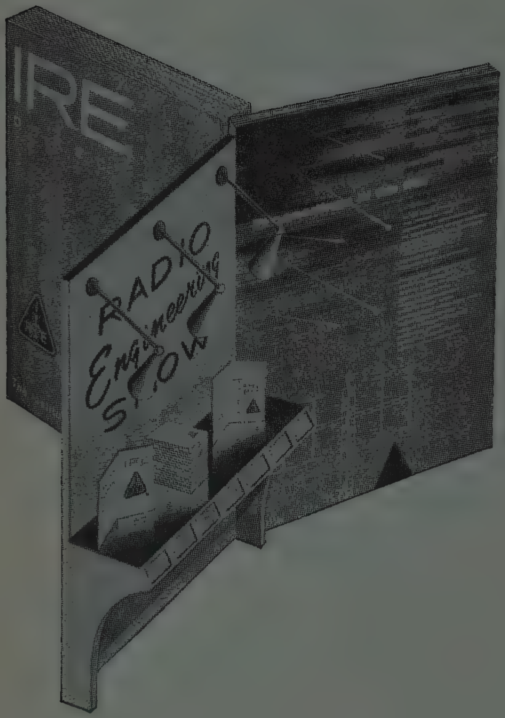
WESTON

Instruments

A DAYSTROM UNIT

the three sides to sell in RADIO AND ELECTRONICS

The fellows who write the big orders in this business know their market. And they know that hitting that market with year-in, year-out consistency is a three-way proposition. The reason is simple. The radio and electronics engineers of America believe in and wholeheartedly support these three *Institute of Radio Engineers'* services.



Proceedings of the IRE

Here's the engineer's monthly fact sheet — with more pages, more editorial features, and more readers than any publication in its field. Over 52,000 radio-electronics engineers read *Proceedings* because they want to know what's going on and they've discovered *Proceedings* is the place to find out. It's on top of the latest developments in this fast-moving, fast-expanding field.

IRE directory

More than 1,000 pages long, with circulation well above the 50,000 mark, this unique annual covers the radio-electronics industry from stem to stern. In the Directory you'll find a pinpointed classification of 3,500 manufacturers and 1,500 distributors of radio and electronic equipment along with the products they handle. To help you clinch the sale the *IRE Directory* lists the business phone numbers of 3,200 firms. No wonder they call the *IRE Directory* the "Bluebook" of the radio-electronics industry.

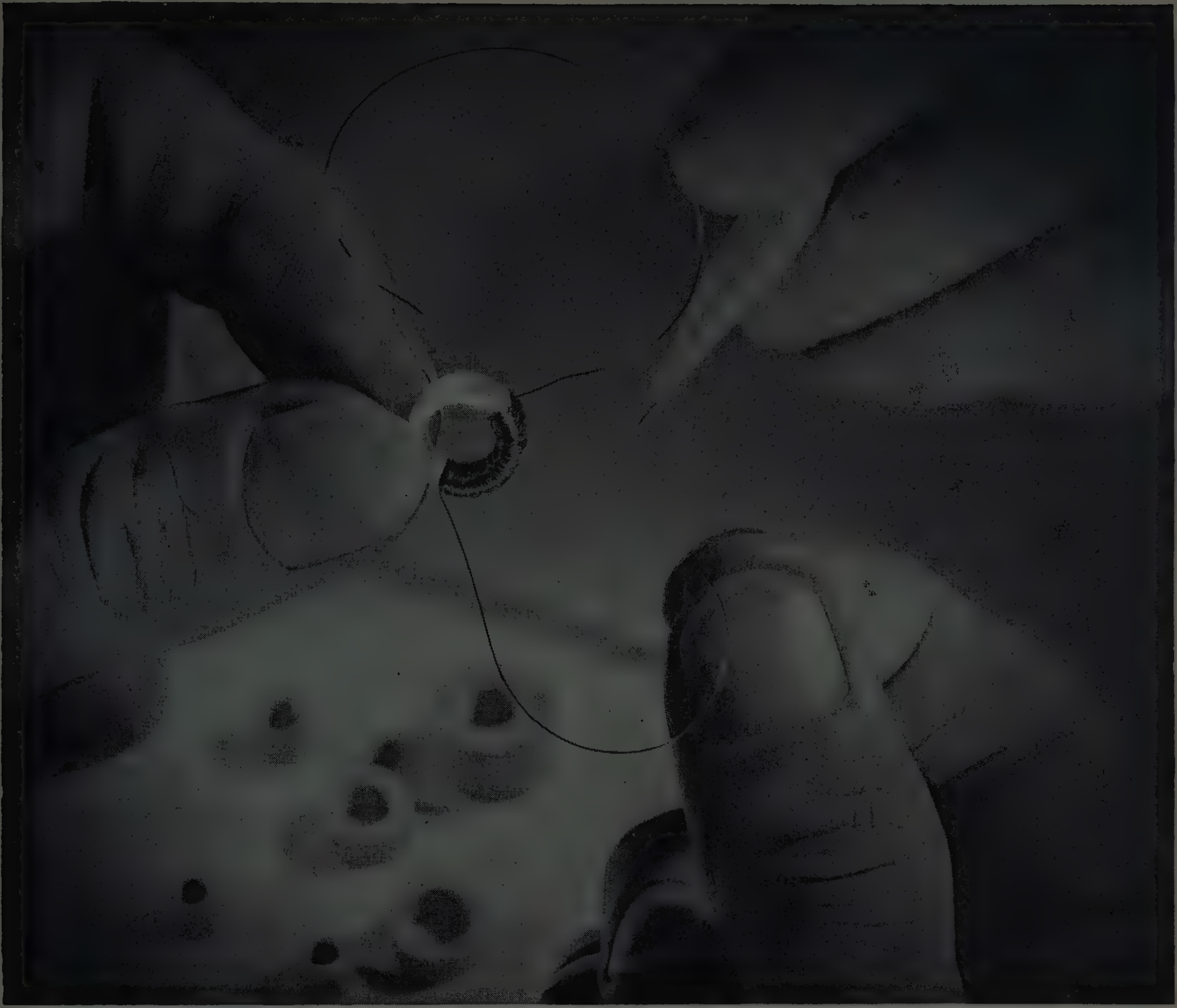
Radio Engineering Show

The radio-electronics "spectacular" held annually at New York's mammoth Coliseum. Here's your personal introduction to 50,000 radio-electronics engineers — the men who use the products you sell and manufacture. They're eager to see your new equipment, to listen to your new ideas. This year, don't pass up this golden opportunity to meet them on their home grounds.
For all the details:

The Institute of Radio Engineers

ADVT. DEPT.: 72 W 45th STREET • New York 36, N. Y.
MUrray Hill 2-6606

KEEP UP-TO-DATE ON MAGNETICS



Just published—bobbin core guaranteed performance limits!

We have just published new data which will light the way to ease, sureness and accuracy for the designer who works with tape wound bobbin cores.

First—and this is a "first"—we have published *guaranteed* maximum and minimum performance limits for all of our bobbin cores. Computer-type designers who would like open-circuit characteristics, guaranteed core flux and guaranteed squareness will find them all here.

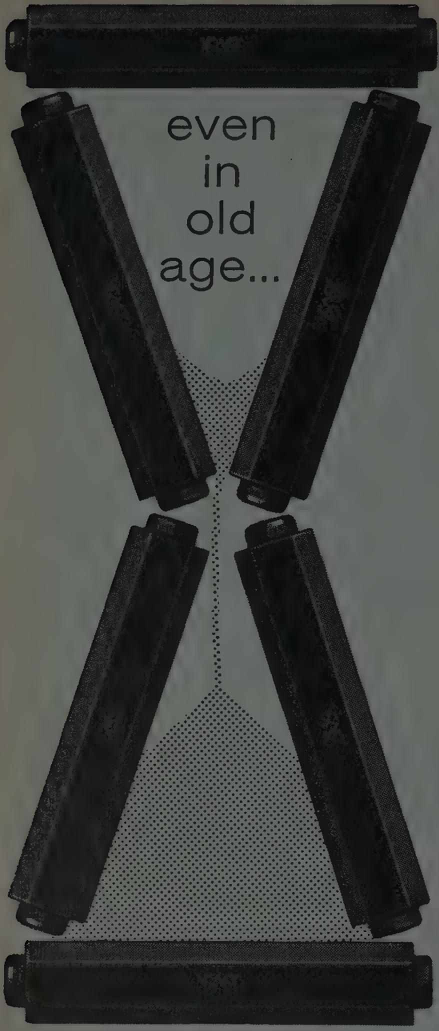
Second—and this too is a "first"—we have published the first fundamental data on characteristics of bobbin cores for circuit designers. Need core total flux characteristics as related to core material? Want switching time vs drive levels? How about typical spreads of core characteristics? It's all yours.

Third—and this too is a "first"—we automatically give you test data for prototype orders. With your prototype cores come open-circuit outputs, total flux, and squareness data. You get a basic understanding of the core's characteristics under specific test conditions. More important, when you re-order production quantities, you will be able to duplicate the core around which you designed your circuit.

Last—but still a "first"—to show that we manufacture as well as publish, we have designed the first bobbin core protective cap which will permit normal potting procedures for all sizes of steel and ceramic bobbins. Our "Poly Caps" have virtually no effect on dimensions—and will not soften or deform under manufacturing or operational temperatures. We'd like to show you samples.

At what stage do you want to start? Whether it's design data, prototype data and cores, or production quantities of our "Performance-Guaranteed" bobbin cores—you can get what you need by writing Magnetics, Inc., Department I-48, Butler, Pennsylvania.

MAGNETICS inc.



S.S.White

MOLDED RESISTORS

retain their values!

S. S. WHITE Molded Resistors retain their original values and never deteriorate due to age!

S. S. WHITE resistors serve dependably in hundreds of commercial . . . industrial . . . and scientific applications. They are characterized by low noise level . . . precision . . . stability . . . negative temperature and voltage coefficients. Non-hydroscopic base withstands temperature and humidity. They are compact, have excellent stability and mechanical strength.

For full details, write for our Bulletin 5409. We'll be glad to help you apply these high-quality, "all-weather" resistors to your product. Just drop us a line.

FIXED RESISTANCE VALUES
RANGE FROM 1000 OHMS TO
10,000,000 MEGOHMS!

65X Molded Resistor .... 1 watt
80X Molded Resistor .... 3 watts

S.S.White

S. S. WHITE INDUSTRIAL DIVISION
10 East 40th Street, New York 16, New York
Dept. PR
Western Office:
1839 West Pico Blvd., Los Angeles 6, Calif.

Professional Group Meetings

(Continued from page 73A)

Philadelphia—May 20

"New Applications of the Transfluxor," D. L. Nettleton, RCA.

Washington—May 14

"Infrared Detectors," Earl Plyler, Radiometry Section, NBS.

ELECTRON DEVICES

Boston—May 13

"Large Signal Behavior of Junction Transistors," Chaang Huang, Sylvania Electric Products, Inc.

Los Angeles—May 19

"Junction Transistor Tetrodes," D. W. Boensel, California Institute of Technology.

Washington—May 19

"New Adventures in Electronics," C. N. Hoyler, RCA.

ELECTRONIC COMPUTERS

Akron—May 28

"The Application of Computers to Industrial Process Control," Irving Lefkowitz, Case Inst. of Technology.

Chicago—April 11

"Logical Design Features of Argonne National Laboratory Computer 'George,'" D. A. Flanders, Argonne National Lab.

Dayton—April 17

"Trends in Computer Research and Engineering," T. Hollar, L. K. Sanders and Dr. Standsbury, National Cash Register, Inc.

Dayton—March 6

"Inclemental Techniques in Digital Computations," Max Palevsky, Packard-Bell Computer Corp.

Pittsburgh—May 6

"The Philco TRANSAC S-2000 Digital Computer," William Doherty, Herbert Jacobsohn and Eugene Hebert, Philco Corp.

San Francisco—May 27

"Future Computers—Analog, Digital and Hybrid Types," W. F. Bauer, Ramo-Wooldridge Corp.

ENGINEERING MANAGEMENT

Los Angeles—May 20

Tour through CBS-TV Studios.

Metropolitan New York—June 2

"An Engineer's Visit to the Soviet Union," John Dyer, Airborne Instrument Lab.

(Continued on page 80A)

New "E" Relay
interchangeable with
many other makes
.375
.375
1 9/64
.375
.750

Stromberg-Carlson's new type "E" relay combines the time-proven characteristics of the type "A" relay with a mounting arrangement common to many other makes.

As the sketch above shows, our new frame mounting holes and coil terminal spacing allow you to specify these relays—*of "telephone quality"*—interchangeably with brands you have been using. Costs are competitive and expanded production means *prompt delivery*.

Welcome engineering features of the new "E" relay are—

★**Contact spring assembly:** maximum of 20 Form A, 18 B, 10 C per relay.

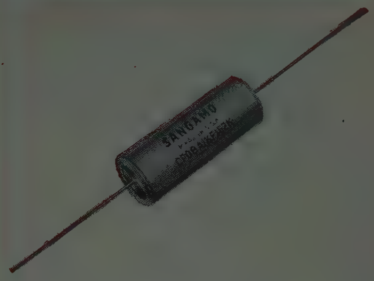
★**Coil:** single or double wound, with taper tab or solder type terminals at back of relay.

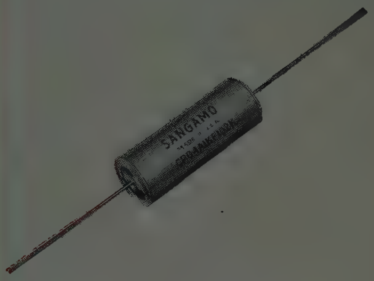
★**Operating voltage:** 200 volts DC maximum.

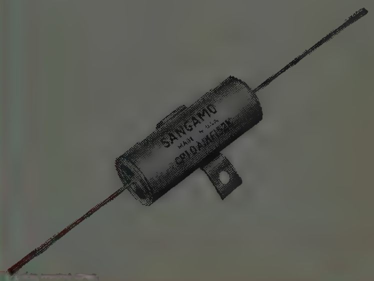
You may order individual can covers in a choice of 3 sizes for the new relay, as well as for our type "A" and "C" relays.

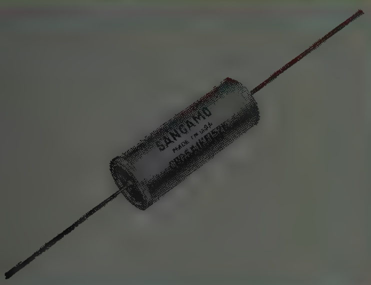
For complete details and specifications on the "E" relay and other Stromberg-Carlson relays, send for your free copy of Catalog T-5000R.

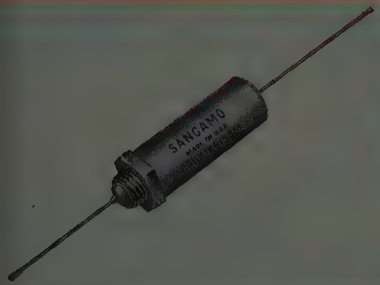
STROMBERG-CARLSON
A DIVISION OF GENERAL DYNAMICS CORPORATION
TELECOMMUNICATION INDUSTRIAL SALES
115 CARLSON ROAD, ROCHESTER 3, N. Y.











MINIATURIZED
military type CAPACITORS

FOR YOUR MOST CRITICAL APPLICATIONS

SANGAMO TYPE S CAPACITORS

HERMETICALLY SEALED PAPER TUBULARS

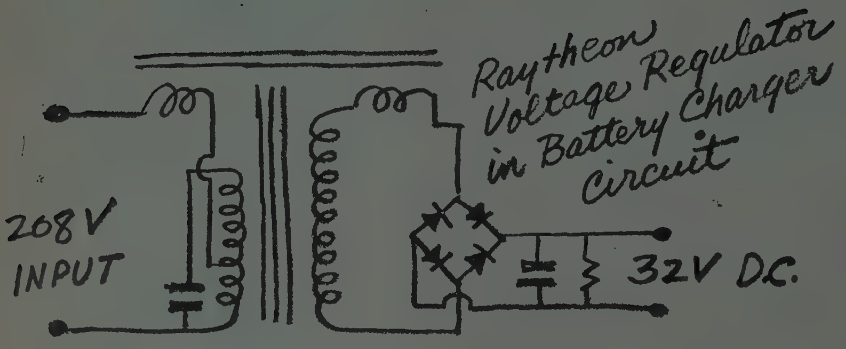
These high reliability subminiature capacitors are encased in brass tubular metal cases, hermetically sealed with Sangamo's exclusive "INNERSEAL" glass-to-metal terminal that gives utmost protection against leakage under severe operating conditions.

Sangamo Type S Capacitors meet the performance requirements of MIL-C-25A, MIL-C-14157A, and MIL-C-26244USAF. For design convenience, several choices are available with regard to tolerances, circuit assembly, lead styles, mounting brackets, insulating sleeve, and inductive or non-inductive sections. Engineering Catalog No. 2421 gives complete information. Popular styles and ratings are available from stock.

SANGAMO ELECTRIC COMPANY
SPRINGFIELD, ILLINOIS

SC58-4

IS CONSTANT VOLTAGE
POSSIBLE IN THESE
CHANGING TIMES?



...Basically, the problem is a classical one of semantics. Higher minds than ours have pondered this question for centuries.

As a practical exercise, let us examine the case of voltage regulation reference source in the power supply circuit shown above. This passive network corrects input voltage changes of more than ±15% of rated outputs and controls them to within ±½%...a feature that is highly important in keeping storage batteries alive longer.

The point is that constancy is a relative term understood only against a background of change. The answer then to the initial question is "yes"...constant voltage is possible.

You can get the Complete Story about voltage regulators from the higher minds at Raytheon by writing to:

VOLTAGE REGULATOR MAN
Raytheon Manufacturing Company
Magnetic Components Department
Section 6120
Waltham 54, Massachusetts

RAYTHEON
Excellence in Electronics

Professional Group Meetings

(Continued from page 78A)

Washington—April 7

"Problems of Engineering Management," M. A. Williamson, Pennsylvania State Univ.

ENGINEERING WRITING & SPEECH

Washington, D. C.—May 20

"Getting New Business Through Effective Proposal Presentations," Michael Ingrisano and W. T. Cradlin, Melpar, Inc.

INFORMATION THEORY

Washington, D. C.—June 10

"Some Topics in Detection Theory," David VanMeter, Melpar, Inc.

Washington—May 8

"Information Theory Aspects of Pattern Recognition," Oliver Selfridge, Lincoln Lab.

INSTRUMENTATION

Florida West Coast—May 21

"Symposium on Instrumentation Electronic Equipment," Arthur Lynch, Arthur Lynch Associates.

Washington, D. C.—May 26

"Measurement of Alternating Voltage at Frequencies up to 3 Mc/s," F. L. Hermach, National Bureau of Standards; "RF Power Measurements from 5 Mc/s thru Microwaves," C. M. Allred, National Bureau of Standards.

INSTRUMENTATION
ELECTRON DEVICES
NUCLEAR SCIENCE

Washington—April 21

"Controlled Thermonuclear Fusion and its Meaning for the Radio Engineer," E. W. Herold, Radio Corp. of America.

MEDICAL ELECTRONICS

Boston—April 8

"Use of Computers to Process Electrophysiological Signals," M. H. Goldstein, Mass. Inst. of Technology.

Los Angeles—May 19

"Electroencephalography and Instrumentation," R. D. Walter, U.C.L.A. Medical Center.

Philadelphia—May 14

"Images from Isotopes," Richard Chamberlain and John Hale, Univ. of Pennsylvania.

(Continued on page 84A)

In Engineering—meet a man who gets results

Painting pictures, designing missile systems . . . creativity typifies the General Mills engineer

Meet Dr. Howard Baller, art collector, amateur painter, and Director of Engineering at the Mechanical Division of General Mills. At the office or at the easel, creativity is the mark of his endeavor.

This same creativity is the distinguishing feature of the well equipped, highly talented engineering department he directs. It is seen in every staff member—reflected in every one of their projects, some of which include . . .

SYSTEMS

- Airborne Early Warning
- Missile
- Geodetic and Survey
- Ground Support Equipment
- Naval Ordnance
- Space Vehicle Guidance

SUBSYSTEMS

- Inertial Guidance and Navigation
- Special Purpose Electro-mechanical Analogue Computers
- Special Purpose Digital Computers
- Microwave Radar and Beacons
- Fuzing and Arming Devices

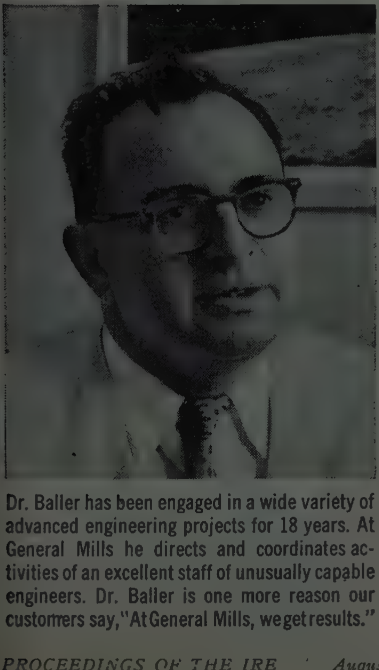
We team creative engineering with intensive research and fine precision manufacturing to serve the nation's most exacting customers. We'd like to serve you.

MECHANICAL DIVISION

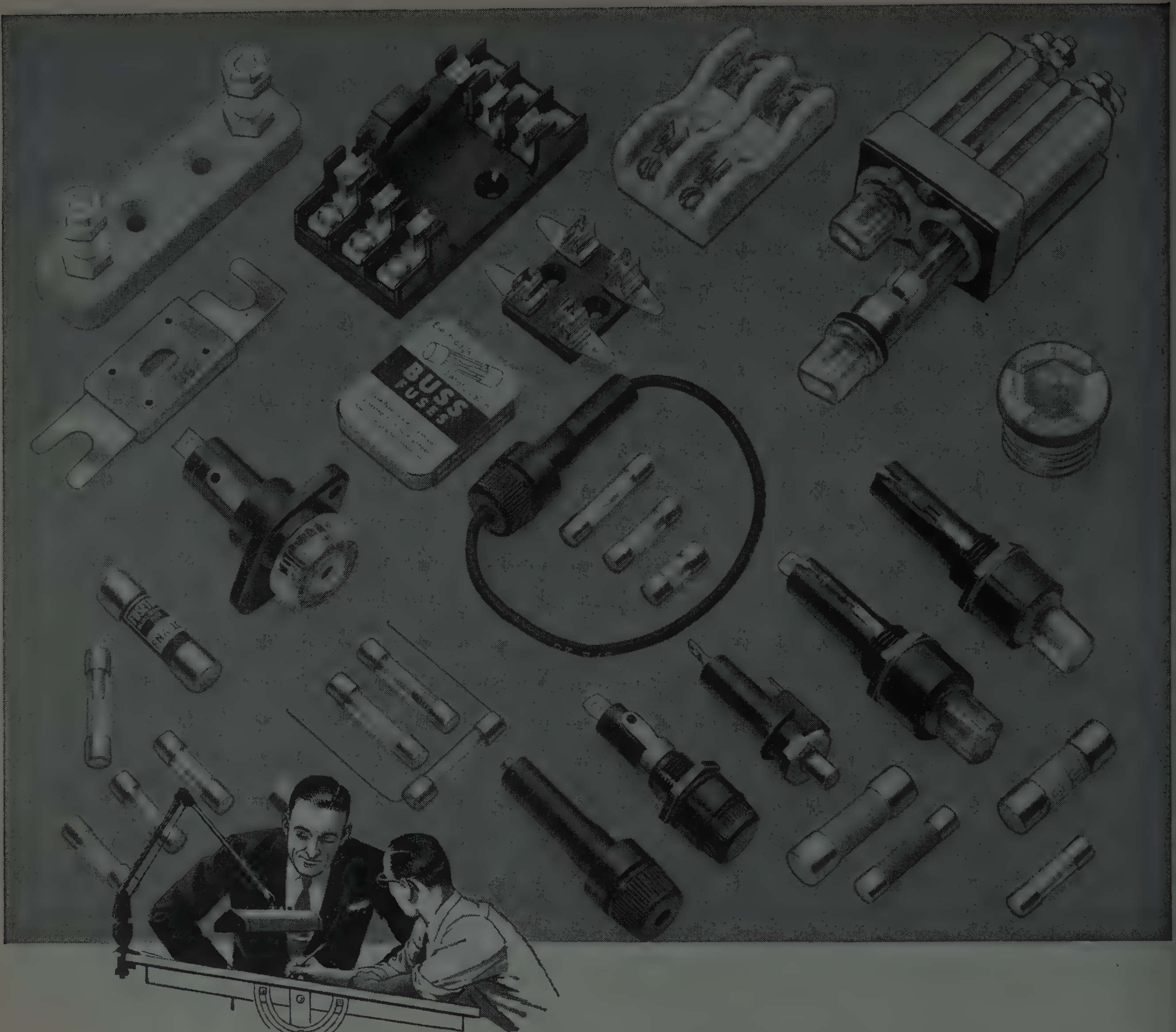
1620 Central Avenue • Minneapolis 13, Minnesota

Intensive Research • Creative Engineering • Precision Manufacturing

General Mills



Dr. Baller has been engaged in a wide variety of advanced engineering projects for 18 years. At General Mills he directs and coordinates activities of an excellent staff of unusually capable engineers. Dr. Baller is one more reason our customers say, "At General Mills, we get results."



For Safe, Dependable Electrical Protection

. . . Standardize on BUSS Fuses!

To make sure of proper operation under all service conditions . . . every BUSS fuse is tested in a sensitive electronic device that automatically rejects any fuse not correctly calibrated, properly constructed and right in all physical dimensions.

This careful testing is your assurance BUSS fuses will provide equipment with maximum protection against damage due to electrical faults.

Just as important, BUSS fuses will not give a false alarm by blowing needlessly. Shutdowns due to faulty fuses blowing without cause are eliminated.

By specifying dependable BUSS fuses, you help safeguard the good name of your equipment for quality and reliability.

Complete Line—There is a complete line of BUSS fuses in sizes from 1/500 ampere up . . . plus a companion line of fuse clips, blocks and holders.

If your protection problem is unusual . . .

. . . let the BUSS fuse engineers work with you and save you engineering time. If possible, they will suggest a fuse already available in local wholesalers' stock, so that your device can be easily serviced.

For more information on the complete line of BUSS and FUSETRON Small Dimension Fuses and Fuseholders, write for bulletin SFB.

Bussmann Mfg. Division, McGraw-Edison Co., University at Jefferson, St. Louis 7, Mo.

BUSS fuses are made to protect—not to blow, needlessly

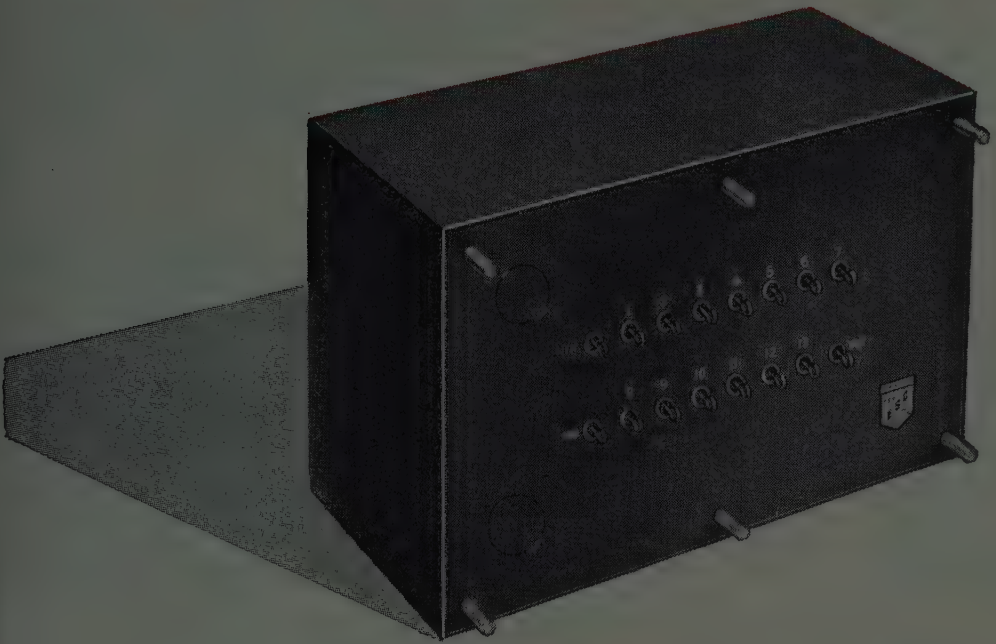
858

FUSETRON
TRUSTWORTHY NAMES IN ELECTRICAL PROTECTION
BUSS

Buss makes a complete line of fuses for home, farm, commercial, electronic, automotive and industrial use.

Because its 145 to 1 delay-to-rise-time ratio
was considered impossible

THIS IS THE DELAY LINE THAT COULDN'T BE MADE



...BUT ESC MADE IT!

Compare the new ESC Delay Line Model 51-43 with these competitive units:

TYPE	TOTAL DELAY	RISE TIME	VOLUME, INCHES	Zo OHMS	MAX. NO. PULSES	PULSES PER CU. IN.	TOTAL INSERTION LOSS	INSERTION LOSS PER PULSE	MERIT* FACTOR	MIN. PULSE LENGTH
**Commercial Air Core Delay Line	4.6 µs.	0.1 µs.	92.7	430	23	.248	7 db	.304 db	0.816	.2 µs.
**Commercial Ferrite Core Delay Line	12 µs.	0.26 µs.	41.2	500	23.1	.56	2 db	.0866 db	6.45	.52 µs.
**Commercial Ferrite Core Delay Line	200 µs.	4.4 µs.	74.4	500	22.8	.306	2 db	.0876 db	3.5	8.8 µs.
**Commercial 1350 Ohm Distributed Line	12 µs.	0.44 µs.	77.7	1350	13.6	.175	12.4 db	.911 db	0.192	.88 µs.
**RG 65 U	8 µs.	0.31 µs.	820	950	12.9	.0157	11.5 db	.892 db	0.0176	.62 µs.
ESC Delay Line Model 51-43	20.3 µs.	.14 µs.	115	470	72	.625	2 db	.0278 db	22.5	.28 µs.

$$* \text{ Merit Factor} = \frac{\text{Pulses}}{\text{In.}^3} \div \text{Insertion loss per pulse}$$

**J. R. Anderson, "Electrical Delay Lines for Digital Computer Applications" Transactions of the I.R.E.—June, 1953

exceptional employment opportunities for engineers experienced in pulse techniques

SEE YOU AT THE WESCON SHOW—BOOTH 927

ESC CORPORATION

534 Bergen Boulevard, Palisades Park, New Jersey

no matter how INTRICATE your small space problem...

it can be solved with

MUCON

SUBminiature ceramic capacitors

in 12 versatile ceramic materials

CONCENTRATION on subminiature ceramic capacitors only, has enabled MUCON to develop this art to the highest degree of versatility . . . dependability . . . properties . . . shapes . . . to fulfill any critical requirement in subminiature size.

MUCON's custom facilities are geared to an

"IMMEDIATE SERVICE"

policy no matter the quantity.

Send for catalog/representative.

MUCON CORPORATION
9 ST. FRANCIS ST., NEWARK 5, N. J.

Professional Group Meetings

(Continued from page 80A)

Washington, D. C.—May 8

"Fundamentals of Analog Computation," H. L. Mason, National Bureau of Standards.

MICROWAVE THEORY & TECHNIQUES

Baltimore—April 9

"Characteristics of Dielectric Image Lines at Millimeter Wavelengths," J. C. Wiltse, Johns Hopkins Univ.

Long Island—May 20

"Surface and Leaky Wave Antennas," A. A. Olinver, Microwave Research Institute.

Long Island—April 8

"Kilowave to Microwave Antennas," P. S. Carter, Radio Corp. of America Labs.

Washington—May 7

"Dielectric Image Line Antenna," Murray Hoffman, Litton Industries.

(Continued on page 88A)

PHILCO®

Transistor Center, U.S.A.

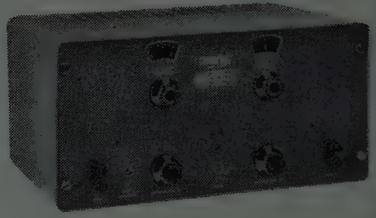
...your FIRST source for all transistor information and prices

TRANSISTOR CENTER U.S.A.

PHILCO CORPORATION
Lansdale Tube Co. Div.
Lansdale, Pennsylvania

Krohn-Hite

VARIABLE ELECTRONIC FILTERS



MODELS 330-A and 330-M

FEATURING
- ULTRA-LOW FREQUENCY COVERAGE
- 100,000 to 1 FREQUENCY RANGE IN ONE INSTRUMENT
- DIRECT FREQUENCY CALIBRATION

The Krohn-Hite Filter Line

Model	Type	Frequency Range	Price
310-AB*	Band Pass	20 cps to 200 kc	$295.00
330-A*	Band Pass	.02 cps to 2 kc	$475.00
330-M*	Band Pass	0.2 cps to 20 kc	$475.00
340-A	Servo	.01 cps to 100 cps	$385.00
350-A*	Rejection	.02 cps to 2 kc	$475.00
360-A*	Rejection	20 cps to 200 kc	$295.00

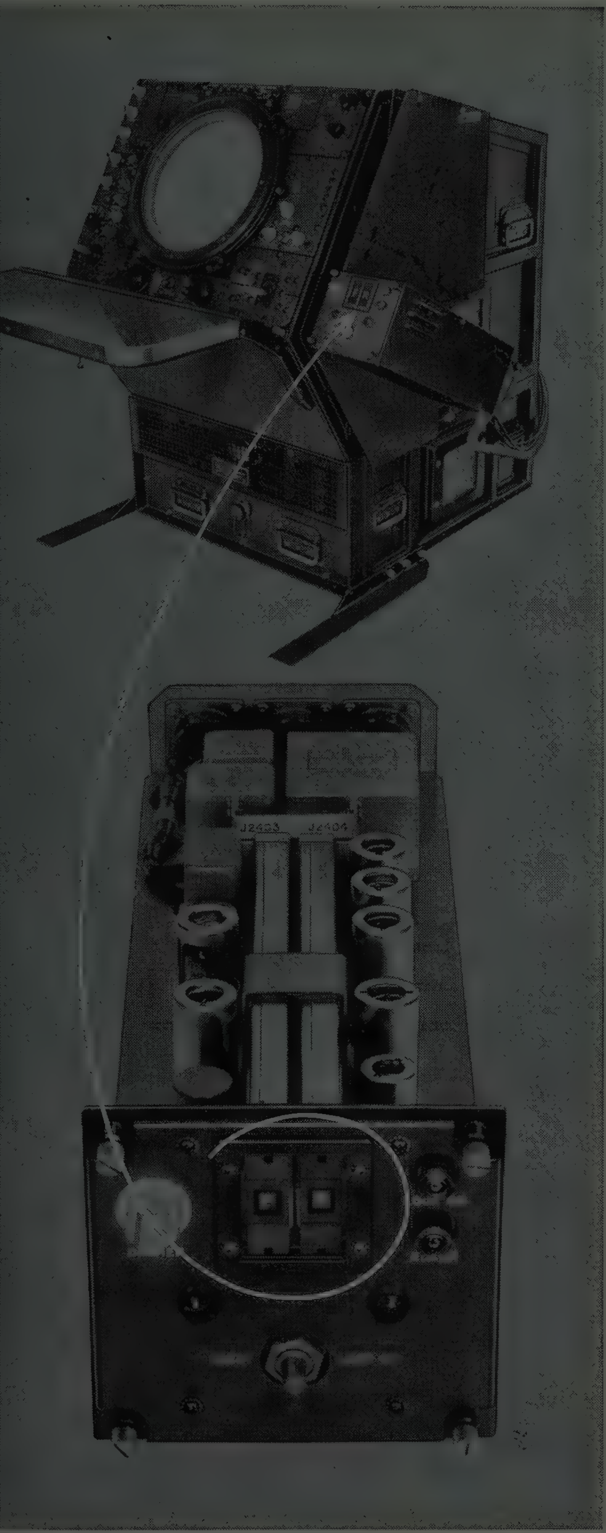
*Available for rack mounting at $5.00 additional.

For further information on:
- Filters
- Power Supplies
- Oscillators
- Power Amplifiers

write for our free catalog D

Krohn-Hite CORPORATION
580 MASSACHUSETTS AVENUE
CAMBRIDGE 39, MASS., U. S. A.

Union Indicators help Hazeltine radar-display unit identify aircraft



Just a glance at the little black box on the right side of this radar-display unit tells the operator whether an approaching aircraft is friend or foe. The IFF response is processed by radar equipment and is displayed in the Hazeltine unit by Alpha-Numerical Indicators manufactured by Union Switch & Signal. The radar-display unit is manufactured by Hazeltine Electronics Division of Hazeltine Corporation, Little Neck, New York. Hazeltine chose Union Switch & Signal's Alpha-Numerical Indicators because of their compact design and supreme reliability, and for the features listed below.

Two Types—Union Switch & Signal makes two types of Data Display Indicators: Digital types, displaying 10, 12, or 16 characters on a wheel, and Alpha-Numerical types, displaying up to 64 characters on a Mylar belt. Character assignments can be furnished as required.

Translation—Both Digital and Alpha-Numerical Indicators operate directly on binary codes on a null-seeking basis, eliminating the need for external equipment for translation from binary to decimal code as required for other display devices.

Visual Read-Out—The design of the Indicator packages is such that when indicators are mounted in rows, the digital read-out is presented with excellent continuity and visibility.

Infinite Retentivity—Since the method of operation is of the null-seeking type, the Indicators require power only during the response time, and once positioned, retain the data both visually and electrically until such time as a new code is transmitted.

Electrical Read-Out—The design of the decoding and control portion of the Indicators inherently provides electrical read-out of data in the same form as the input. The data can be read out of the Indicators on a continuous basis or as often as desired without erasing the stored information.

Call or send the coupon for complete information about indicators and other electronic equipment manufactured by Union Switch & Signal.

COMPLETE FACTS

Union Switch & Signal, Advertising Dept.
Pittsburgh 18, Pennsylvania

Please send information on the following:

- ☐ New 4PDT relay which meets every requirement of MIL-R-25018.
- ☐ Catalog of other miniature dc and ac relays.
- ☐ Digital and Alpha-Numerical Indicators for data display.

Name__________ Position__________

Firm__________

Address__________

City__________ Zone____ State__________

See You At The Wescon Show
August 19-22
BOOTH #503-504
Pan Pacific Auditorium
Los Angeles, California

"Pioneers in Push-Button Science"

UNION SWITCH & SIGNAL
DIVISION OF WESTINGHOUSE AIR BRAKE COMPANY
PITTSBURGH 18, PENNSYLVANIA

FOTOCERAM circuit board blanks are made photographically. All holes and shapes are produced by simple exposure to light, heat, and an etching operation.

This is a FOTOCERAM printed circuit

. . . an unusual new type of printed circuit board

Reliable through-plate holes • The good adhesion of the circuit runs applies also to the through-plate holes because both are produced with one plating operation.

Excellent resolderability • We have removed and resoldered components over twenty times on a FOTOCERAM board without damage to circuit runs or through-plate holes. And this is *without* using adhesives to bond the copper to the board.

Dimensional stability • Rigid structure of FOTOCERAM prevents unusual design considerations—eliminates problem of warp and twist.

Good adhesion • It takes 12-25 pounds to peel a one-inch copper strip from a FOTOCERAM board.

Exceptional pull strength • 1400 pounds per square inch.

No water absorption • FOTOCERAM'S nonporous—zero water absorption.

Non-flammable

No blisters • FOTOCERAM never blisters. We put it through repeated 15-second cycles of copper metallizing at 500°F. and could not find a single blister or sign of peeling or failure.

Other properties:

Dissipation factor		
	1 mc @ 20°C.	0.006
	@ 200°C.	0.014
Dielectric constant		
	1 mc @ 20°C.	5.6
	@ 200°C.	6.3
Loss factor	1 mc @ 20°C.	0.034
	@ 200°C.	0.088

For more information, write for our Data Sheet on FOTOCERAM.

Corning means research in Glass

CORNING GLASS WORKS, Bradford, Pa.

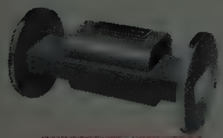
Electronic Components Department

NOW 99

Different Attenuators in The

PRD PACEMAKER LINE

LOOK down the line of these PACEMAKERS. Diverse in function, they are all characterized by simplicity of operation, higher accuracy, greater strength factors . . . and low cost resulting from volume manufacturing. PRD is the largest maker of microwave instrumentation, the PRD PACEMAKER LINE is more complete than any other.


WAVEGUIDE ISOLATORS

See Catalog Page A-21

ROTARY STANDING WAVE DETECTOR

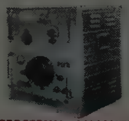
See Catalog Page B-13

DIRECTIONAL COUPLERS

See Catalog Page C-9

EXPANDED SCALE FREQUENCY METERS

See Catalog Page D-12

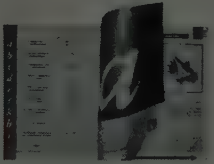

SPECTRUM ANALYZERS

See Catalog Page F-13

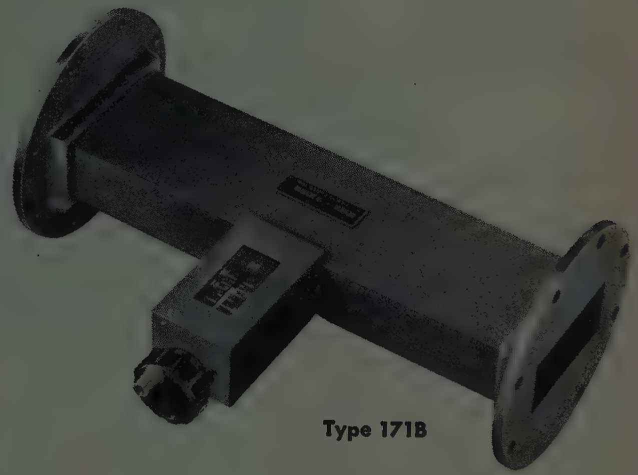
THERMISTOR AND BOLOMETER MOUNTS

See Catalog Page E-15

SEE the latest models of the most complete line of microwave instrumentation at PRD's WESCON Booths 1357-1358.



GET this new 160 page PRD Microwave Catalog, largest and most informative ever published, available without cost or obligation to those actively engaged in microwave work. Write for your copy, giving your name and title on your company letterhead.


Type 171B

LEVEL SET ATTENUATORS

Designed for convenient adjustment of power level and for use as padding devices, these units cover the 2.6 to 18.0 KMC/s range. In each of these 6 standard waveguide sizes, a 20 db and 40 db attenuation range is offered. Well-shielded attenuation is achieved by means of a ruggedized, shock and moisture resistant element which is mounted parallel to the sidewall of the waveguide. Both ends of this element are matched to provide low VSWR (1.15 maximum). Smooth variation of attenuation is obtained by means of a low backlash, multi-turn drive. Approximate attenuation markings are provided on a scale which is calibrated near the center of the waveguide frequency range.

For complete specifications, see page A-17 of the NEW PRD Catalog.

POLYTECHNIC RESEARCH & DEVELOPMENT CO., INC.
202 Tillary Street • Brooklyn 1, N.Y.

Lapp
CERAMIC
RESISTOR
CORES

A special porcelain body is used in the production of Lapp Resistor Cores. It provides a flawless surface of such nature as properly to receive a uniform deposit of carbon or boro-carbon. It also has a temperature coefficient of expansion matched to that of the deposited film . . . to provide a constant resistance against temperature change. These resistor cores are produced in close tolerances for straightness, roundness and length . . . they reflect the same quality of workmanship and materials long associated with Lapp. Write for complete information on Lapp Resistor Cores. Lapp Insulator Co., Inc., Radio Specialties Division, 213 Sumner St., LeRoy, N. Y.

Lapp

Professional Group Meetings

(Continued from page 84A)

Military Electronics

Fort Walton Beach—June 2

"Eglin Gulf Test Range Planning," M. P. Brown, Instrumentation Development Lab.

Long Island—April 22

"Sage System," E. N. Myers, U. S. Air Force.

Washington—May 5

"The Production of High Temperatures in Thermonuclear Research," Alan Kolb, U. S. Naval Research Lab.

Nuclear Science

Boston—May 6

"M.I.T. Centralized Data Taking System," Martin Deutsch and N. S. Wall, Mass. Inst. of Technology.

Dayton—March 6

"From Atoms to Automation," W. R. Clore, Industrial Nucleonics.

Washington—May 5

"Production of High Temperatures in Thermonuclear Research," A. C. Kolb, U. S. Naval Research Lab.

Washington—April 21

"Controlled Thermionic Fusion and Its Meaning for the Radio Engineer," E. W. Herold, Electronics Research Lab., RCA.

Production Techniques

Washington, D. C.—April 15

"Need for Increased Productivity," Leon Greenburg, U. S. Department of Labor.

Reliability & Quality Control

Los Angeles—May 19

"Contract Implications of Military Electronics Reliability Requirements," Harry Powell, Ramo-Wooldridge Corp. and Leo Arndt, Hoffman Laboratories.

Philadelphia—May 15

"AN/FST-2 Dependability and Downtime Control," R. E. Killion and Harry Reese, Burroughs Corp. Research Center.

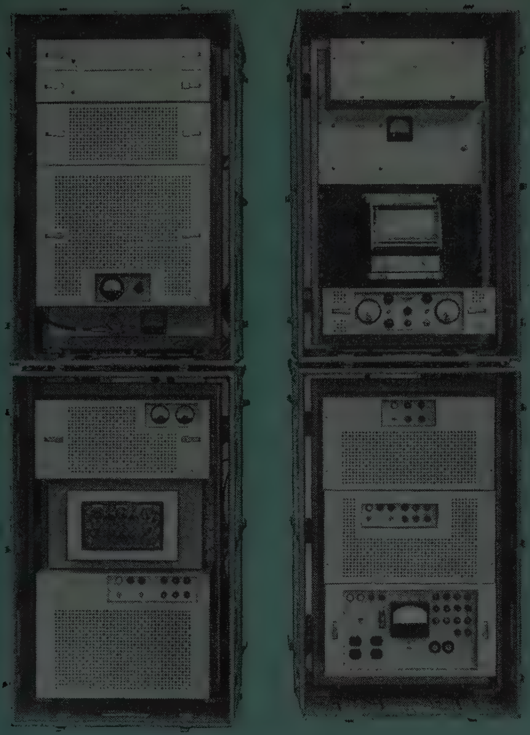
Philadelphia—April 17

"The Challenge of Reliability," W. A. McCrehan, Bendix Corp.

Washington, D. C.—April 30

"A Proposed Program for Monitoring Guided Missile Reliability," Carlton Beyer, Office of Secretary of Defense.

(Continued on page 90A)



Transmitter terminal

Propagation testing made portable

With the continual increase in tropo scatter systems—most of which have been developed and manufactured by REL—has come heightened need for truly portable propagation test equipment to survey proposed scatter transmission paths.

The solution is available in REL's new path test set. Here, for the first time, is packaged transmitting and recording receiving apparatus which is not only small and light, but supremely rugged as well.

Packaged with each set are replacements for all necessary components, many in preassembled form. Parts supply depots are unnecessary, and delays thereby eliminated.

Complete details may be obtained upon request.

SYSTEM

Frequency range: 875 mc to 950 mc*
Power output: 20 or 120 w
Noise threshold: —167 dbw or 0.032 μv in 50 ohms
Recording range: 60 db, 40 db, or 20 db—log-linear
Radio gain: 180 or 188 db
Frequency stability: ±1 pp 10^8 short term
±1 pp 10^7 long term
Primary power: 120 volts ±10%, 50-63 cps
Ambient operating temperature: —18° to +54°C
Non-operating temperature: —65° to +85°C

TRANSMITTER

Modulation: None; cw operation. Provision is made to key power output for identification.
Power output recording: 6-inch strip recorder available

RECEIVER

Bandwidth: 1 kc
Noise figure: 7 db
Recorder: 6-inch strip recorder
Calibration: Signal level and recording linearity by internal means.

MECHANICAL

All cases are 26 1/16″ wide by 20 5/16″ deep by 40 9/16″ high
Cases may be stacked two high during operation.
The weight varies from 200 lbs to 350 lbs depending on case contents.

**Also available in ranges of 435-475 mc & 1750-1900 mc*

Receiver terminal

REL

Radio Engineering Laboratories·Inc
A subsidiary of Dynamics Corporation of America
29-01 Borden Ave · Long Island City 1, N Y
STillwell 6-2100 · Teletype: NY 4-2816
Canadian representative: AHEARN & SOPER CO · 384 BANK ST · OTTAWA

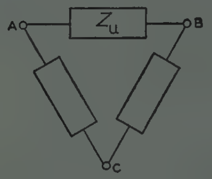
SEE IT AT THE WESCON SHOW
BOOTH 840

Look at these features:

- Exceptional range
- Two, three and four-terminal measurement
- Accuracy to ¼%
- Discrimination to 0.01% of full scale
- Special adaptors cover measurement of liquid conductivity, dielectric and loss factor of solids and liquids, dry joints, switch contact resistance, circuit strays.

Wayne Kerr Universal Bridge, Type B-221

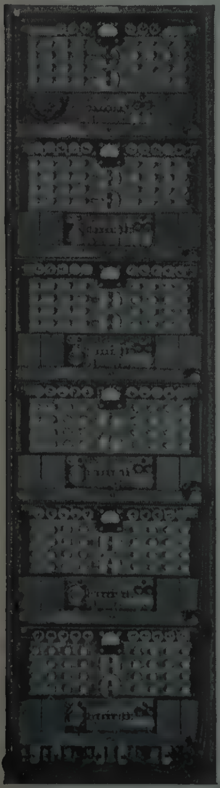
Here's a highly accurate, advanced design transformer ratio arm bridge, with facilities for 2-4 terminal impedance measurement or transfer admittance over an extremely wide range. This instrument permits easy measurement of an impedance between any two terminals, regardless of the presence of other impedances from either or both terminals and a third point; measurement is unaffected by the impedance of the test leads which, therefore, can be of any length.



Z_u measured in circuit

Capacitance: 0.0002$\mu\mu$f to 11μf—±0.25% ±0.0002$\mu\mu$f
Conductance: 10^{-1} to 10^{-8} mhos (10Ω to 100 MΩ)—±0.25% ±0.00002μmho
Inductance: 1mH to infinity—±2% ±1mH
Extended range using the Low Impedance Adaptor: 1μf to 100,000μf—50μΩ to 100Ω—5 mμH to 10 mH
Measuring Frequency: 10,000 rads/sec.

WAYNE KERR CORPORATION
Electronics for Measurement and Control
2920 N. 4th Street
Philadelphia 33, Pa.
Sales, Stock and Service Facilities



MINIATURIZED
CARRIER TELEPHONE SYSTEMS
FOR RADIO AND 4-WIRE CABLE

FOUR OR 24 CHANNELS

Two miniaturized voice-multiplex systems providing four or 24 voice channels over radio or 4-wire cable are available. They have many advantages over earlier designs: high performance, small size, light weight, low cost, circuit simplicity, low power requirements, small number of tubes of a single type only, low operating cost, low maintenance and high reliability.

These systems provide a voice-channel flat within 1 db from 300 to 3500 cycles, for each 4 kc of bandwidth occupied. Each channel is equipped with hybrid, signalling, and dialling circuits for all the standard 2-wire and 4-wire loop options.

The basic unit provides an order-wire and 4 carrier-derived channels. These units can be stacked in groups of 2, 3, 4 or 5 by means of a group modem to provide 9, 14, 19 or 24 channels. Full flexibility is provided for dropping and inserting channel groups at repeater and terminal points. Moderate lengths of 4-wire cable or open-wire line may be inserted between the multiplex equipment and the radio terminals.

24-channel carrier-telephone terminal complete with hybrids, ringing and dialling circuits, and test facilities. Dimensions are 58″ high, 16″ wide and 8″ deep. Power input 250 watts. Weight 326 lbs.

RADIO ENGINEERING PRODUCTS
1080 UNIVERSITY ST., MONTREAL 3, CANADA
TELEPHONE UNiversity 6-6887
CABLES RADENPRO, MONTREAL

Professional Group Meetings

(*Continued from page 88A*)

TELEMETRY & REMOTE CONTROL

Dayton—April 3

"Statistical Telemetry," A. S. Westneat, Applied Science Corp.

Los Angeles—April 15

"Telemetering, The Explorer Satellite," J. F. Koukol, Jet Propulsion Lab.; "Telemetering Receiver Improvement," G. E. Gilchriest, Jet Propulsion Lab.

Philadelphia—May 14

"Project Farside," R. C. Elton, University of Maryland.

San Francisco—April 15

"Telemetering the Explorer Satellite," Lee Randolph, California Institute of Technology.

San Francisco—March 18

"P.C.M.—Fact or Fiction," Peter Dietz, Radiation, Inc.; "Technical Factors Influencing Choice Between Pulse Code and Frequency Code Data Transmission System," E. A. Ragland, Bendix Aviation Corp.

VEHICULAR COMMUNICATIONS

Detroit—May 28

"A Three Channel VHF Emergency Radio Telephone System," Garth Hawley, Michigan Bell Tel. Co.

Philadelphia—May 20

"Sea-Going Wireless Comes of Age," A. F. Miller, Atlantic Refining Co.

Washington—May 26

"Automatic Power Control for Communications Transmitters," N. H. Shepherd, General Electric Co.

You find facts faster with the IRE DIRECTORY

Because the product listings in the IRE DIRECTORY are logically arranged the way an engineer thinks, under four great major classifications that cover the entire radio-engineering field, you can find the product you want, and the names of the firms who make it, faster and more easily than in "terminology-index" types of listings. Advertisements are logically positioned near the product listings which describe them, to give you more information on the companies you'll want to deal with, and the easy-to-use Reader Service Card brings you quick additional data.

NEW!
12AF3
6AF3
TUNG-SOL
MADE IN U.S.A.

Tung-Sol-developed miniature damper tubes cut costs of TV manufacture!

New 6AF3 and 12AF3 permit TV set-makers to profit more fully from economies of automated production.

Two new Tung-Sol damper diodes—6AF3 and 12AF3—bring TV manufacturers substantial dollar-savings through increased efficiency. Modern automatic assembly equipment is better able to process the miniature, button-stem dampers than prior octal-base types. Also, the new types allow standardization of tube and socket size—a big plus in printed circuit usage.

In addition to these cost-cutters, 6AF3 and 12AF3 offer premium performance. They approach the high ratings of the 6AU4GTA and 19AU4GTA . . . have the same heater power as the 6AX4GT and 12AX4GTA. Set-testing under actual overload conditions indicates the new tubes carry a greater "safety factor" than any previous damper.

The economy and top-flight quality of the 6AF3 and 12AF3 characterize the entire Tung-Sol tube line. For complete data on the new miniature dampers . . . to fill any entertainment socket, contact: *Tung-Sol Electric Inc., Newark 4, New Jersey.*

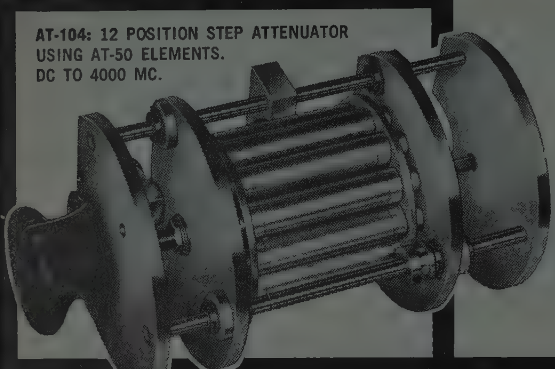
New Tung-Sol miniature dampers
compared with types they replace

	BASING	LOAD-RATING	HEATER-RATING
6AF3 12AF3	Miniature	185ma*	6.3v, 1.2a 12.6v, 0.6a
6AX4GT 12AX4GTA	Octal	125ma†	6.3v, 1.2a 12.6v, 0.6a
6AU4GTA 19AU4GTA	Octal	190ma†	6.3v, 1.8a 18.9v, 0.6a
12D4	Octal	145ma†	12.6v, 0.6a

*According to Design Maximum System of Ratings
†According to Design Center System of Ratings

TUNG-SOL®

WHATEVER YOUR UHF ATTENUATION NEEDS...

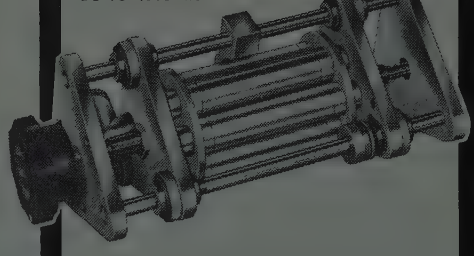

AT-104: 12 POSITION STEP ATTENUATOR USING AT-50 ELEMENTS. DC TO 4000 MC.

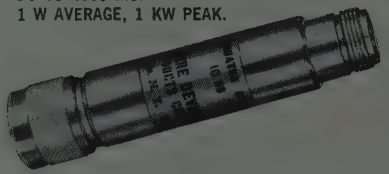
A COAXIAL UNIT FROM EMPIRE DEVICES WILL MEET YOUR REQUIREMENTS

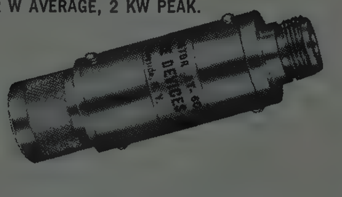
Empire's UHF attenuators are resistive coaxial networks for the frequency range from DC to 4000 MC.

Accuracy is held to ±½ DB, VSWR is better than 1.2 to 1. Any attenuation values up to 60 DB are available. Deposited carbon elements are used for stability and operations at higher pulse levels. Standard impedance is 50 ohms, other values upon request. These units have excellent temperature characteristics and are vibration and shock resistant. Standard connectors are type "N", attenuator pads are also available with type "C".

The attenuators may be obtained as individual pads (AT-50, AT-60), or as multi-position step attenuators AT-103 (six positions) and AT-104 (twelve positions). For even greater flexibility, several step attenuators may be series connected.


AT-103: 6 POSITION STEP ATTENUATOR USING AT-50 ELEMENTS. DC TO 4000 MC.


AT-50: ATTENUATOR PAD, DC TO 4000 MC. 1 W AVERAGE, 1 KW PEAK.


AT-60: ATTENUATOR PAD, DC TO 3000 MC. 2 W AVERAGE, 2 KW PEAK.

For complete technical information about attenuators for your laboratory or production needs, write for free catalog.

NEW YORK—MOunt Vernon 4-7530 • SYRACUSE—GRanite 4-7409 • PHILADELPHIA—SHerwood 7-9080 • BOSTON—TWinbrook 4-1955 • WASHINGTON, D.C.—OLiver 4-6400 • ORLANDO, FLA.—CHerry 1-2128 • ATLANTA—CEdar 7-7801 • DETROIT—BRoadway 3-2900 • CLEVELAND—HIllcrest 2-8080 • PITTSBURGH—ATlantic 1-9248 • ST. LOUIS—EVergreen 5-7728 • CHICAGO—ESterbrook 9-2700 • MINNEAPOLIS—FEderal 5-7172 • DENVER—MAin 3-0343 • FT. WORTH—WAlnut 6-4444 • ALBUQUERQUE—ALbuquerque 5 9632 • LOS ANGELES—TExas 0-7771 • PALO ALTO—DAvenport 3-4455 • SEATTLE—EMerson 2-4812 • HAWAII: HONOLULU 50-2901 • CANADA: STITTSVILLE, ONT.—HAzeldean 56 • SCARBORO, (TORONTO)—AXminster 3-7806 • EXPORT: NEW YORK—MUrray Hill 2-3760

edp

EMPIRE DEVICES
PRODUCTS CORPORATION
AMSTERDAM, NEW YORK
Telephone: VIctor 2-8400

manufacturers of

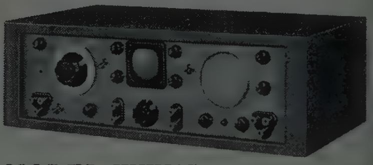
FIELD INTENSITY METERS • DISTORTION ANALYZERS • IMPULSE GENERATORS • COAXIAL ATTENUATORS • CRYSTAL MIXERS

ACCURACIES BETTER THAN 1 PART IN 50 MILLION are free!

WHY NOT USE THEM!

The standard time and frequency transmissions of the National Bureau of Standards radio stations WWV and WWVH provide an invaluable service to laboratories and experimenters throughout the world. Extremely precise (normal transmission stability is within 1 part in 10^9 at WWV and 5 parts in 10^9 at WWVH) audio and radio frequency standards, as well as accurate time intervals and radio frequency propagation warnings, are placed at the disposal of anyone having a receiver capable of tuning to one or more of the transmitting frequencies. Proper use of these facilities can be made to supplement the instrumentation of any laboratory.

The Model WWVC Standard Frequency Comparator is just such an instrument . . . a highly sensitive crystal-controlled radio receiver utilizing WWV and WWVH transmissions.


MODEL WWVC COMPARATOR

A 5-position dial switches *precisely* to any Standard Frequency—2.5, 5, 10, 15, or 20MC. It features built-in oscilloscope and speaker, comparator function selector, Collins plug-in filter for high selectivity, automatic gain and volume controls and adjustable threshold control which eliminates noise and other modulation in tick position.

Send for bulletin #557, "Using Standard Time and Frequency Broadcasts"

− +

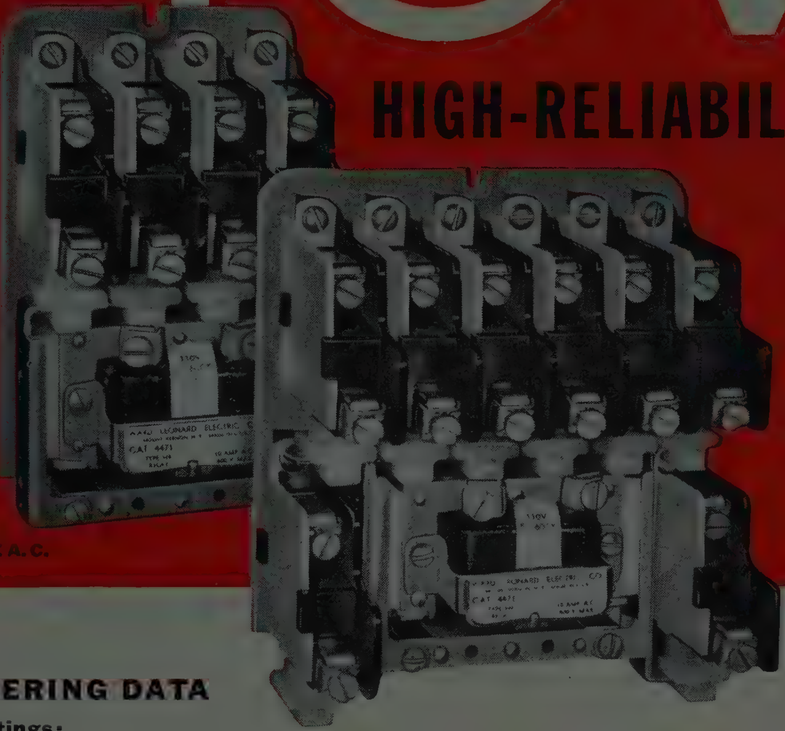
SPECIFIC PRODUCTS

Box 425, 21051 Costanso
Woodland Hills, Calif.

new

HIGH-RELIABILITY RELAYS

- *multi-pole
- *multi-purpose
- *multi-featured



4 POLE A.C.

8 POLE A.C.

ENGINEERING DATA

Contact Ratings:

Volts	A.C. Amperes N.O.	A.C. Amperes N.C.	D.C. Amperes* N.O.	D.C. Amperes* N.C.
115	10	10	6	5
230	10	10	1	1
440	10	10	—	—
600	10	10	—	—

*Non-inductive resistance loads.

Coils: Standard A.C. coils for 110, 208-220, 440, or 550 volts, 50-60 cycles. Standard D.C. coils for 115 or 230 volts. Other coils on special order. **Poles:** 2 to 8, in all combinations of N.O. and N.C. contacts, convertible from N.O. to N.C. and vice versa.

†Dimensions:

A.C.	D.C.	Width	Height	Depth
4 pole	—	3¼″	5 1/16″	3 3/32″
8 pole	—	5⅛″	5 11/16″	3 3/32″
—	4 pole	3⅜″	5¾″	3 3/32″
—	8 pole	5⅛″	5¾″	3 3/32″

†Mounting centers for all models are identical.

Brand new, Type HR solenoid relays are Result-Engineered to function as the "heart" of any control system. The Type HR is designed as a multi-pole relay for piloting machine and process control components where ultra-long life and hi-speed operation are mandatory.

Wiping action contacts insure high electrical reliability; nylon movable contact carriers—separate for each pole—and nylon armature guides minimize operating friction. And, you can add to these features, interchangeable a.c. and d.c. power plants with molded coils.

Simple, fast, easy installation speeds assembly into your equipment, saves time, cuts cost. Accessible front connected coil and contact terminals equipped with pressure connectors . . . no lead lugging needed!

Four basic models with up to eight *unitized* poles maximum; convertible N.O. or N.C. contacts—completely enclosed to keep out dust and foreign particles—make the HR an unusually versatile relay line.

Ask for Ward Leonard Bulletin 4470 for complete technical data. Ward Leonard Electric Co., 35 South Street, Mount Vernon, New York. (In Canada: Ward Leonard of Canada Ltd., Toronto.)

8.6

LIVE BETTER...*Electrically*

WARD LEONARD
ELECTRIC COMPANY
MOUNT VERNON, NEW YORK

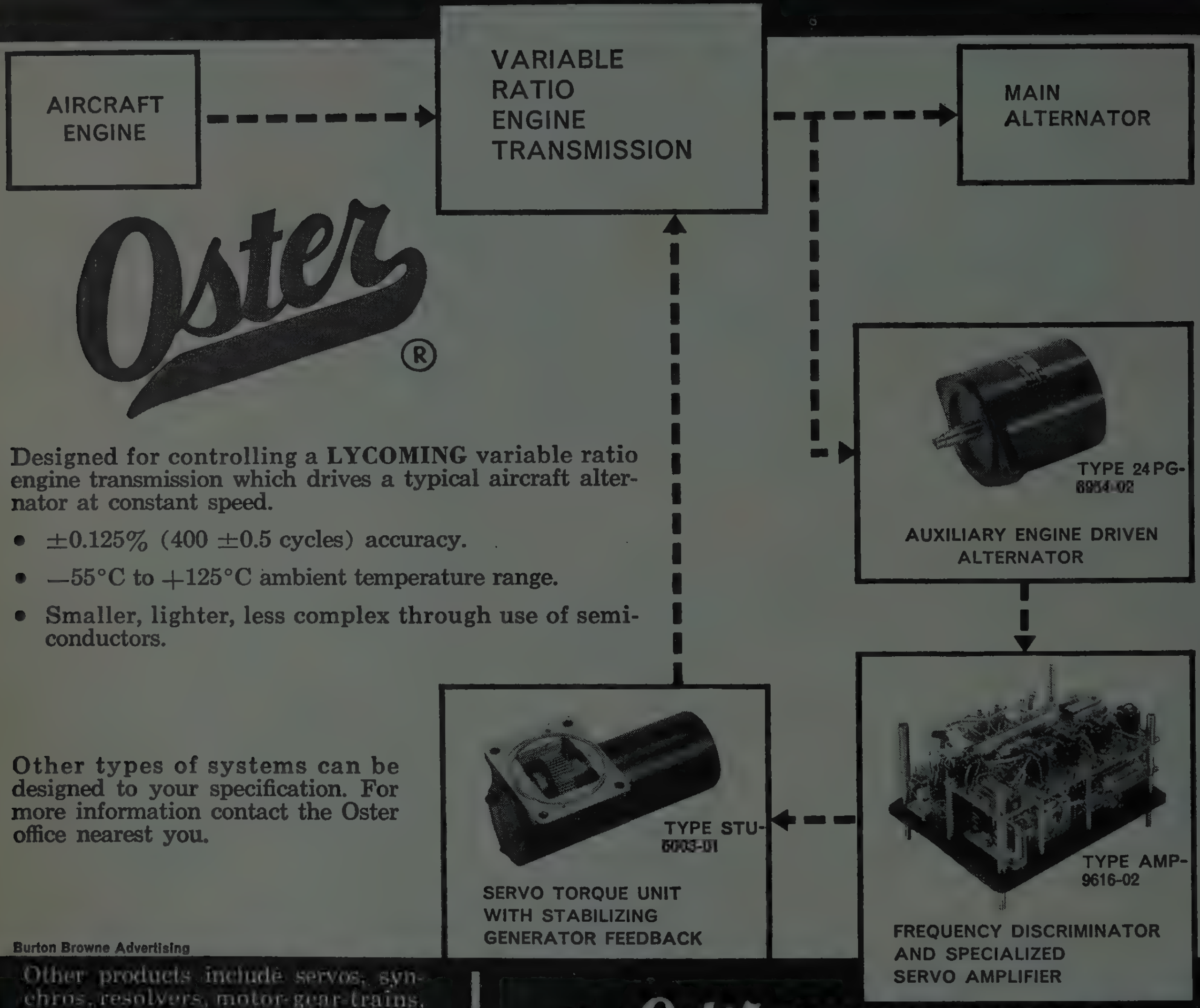
RESISTORS | RHEOSTATS | RELAYS | CONTROLS | DIMMERS

Result-Engineered Controls Since 1892

New Transistorized

FREQUENCY DISCRIMINATOR AND SERVO DRIVEN CORRECTION LOOP

±0.5 ~ accuracy


AIRCRAFT ENGINE
VARIABLE RATIO ENGINE TRANSMISSION
MAIN ALTERNATOR
TYPE 24PG-6954-02
AUXILIARY ENGINE DRIVEN ALTERNATOR
TYPE AMP-9616-02
FREQUENCY DISCRIMINATOR AND SPECIALIZED SERVO AMPLIFIER
TYPE STU-6003-01
SERVO TORQUE UNIT WITH STABILIZING GENERATOR FEEDBACK

Oster®

Designed for controlling a **LYCOMING** variable ratio engine transmission which drives a typical aircraft alternator at constant speed.

- ±0.125% (400 ±0.5 cycles) accuracy.
- —55°C to +125°C ambient temperature range.
- Smaller, lighter, less complex through use of semiconductors.

Other types of systems can be designed to your specification. For more information contact the Oster office nearest you.

Burton Browne Advertising

Other products include servos, synchros, resolvers, motor-gear-trains, AC drive motors, DC motors, servo mechanism assemblies, reference and tachometer generators, servo torque units, actuators and motor driven blower and fan assemblies.

John Oster MANUFACTURING CO.
Your Rotating Equipment Specialist
Avionic Division
Racine, Wisconsin

NEW YORK OFFICE
237 North Main Street
Hempstead, L.I., New York
Phone: IVanhoe 3-4653
TWX Hempstead N. Y. 705

NEW JERSEY OFFICE
517 Lyons Avenue
Irvington, New Jersey
Phone: ESsex 3-2361

WESTERN OFFICE
5333 So. Sepulveda Blvd.
Culver City, California
Phones: EXmont 1-5742
TExas 0-1194
TWX S. Mon 7671

Engineers For Advanced Projects: Interesting, varied work on designing transistor circuits and servo mechanisms.
Contact Mr. Robert Burns, Personnel Manager, in confidence.

BUILT BY KENNEDY..........*the world's largest*

TROPOSPHERIC SCATTER ANTENNA

KENNEDY's new 120 foot Trans-Horizon® Antenna represents today's most advanced concept in tropospheric scatter antenna systems.

This huge reflector is supported by a galvanized steel frame. The feed horn is mounted separately atop a 55-foot steel tower. Wave guides, as well as a ladder for all-weather adjusting, are accommodated within the tower. The "Trans-Horizon 120" can operate in winds up to 180 M.P.H. with 12 inches of ice. Also available: Moderate duty model for winds up to 110 M.P.H.

Here is still another instance of the ability of Kennedy engineers to design and build any antenna within the realm of creative engineering imagination. Can this unmatched know-how be put to work for you?

ANTENNA EQUIPMENT

D. S. KENNEDY & CO.

Route 3A, Cohasset, Mass. EVergreen 3-1200

Down-To-Earth **SOLUTIONS** *to Out-Of-This-World* **PROBLEMS**

Tracking Antennas
Radio Telescopes
Radar Antennas
"Trans-Horizon" Antennas
Tropospheric Scatter
Ionospheric Scatter

7057
7056
7059
7058
7060
061
10
15
5
20
DC VOLTS
from "cruising" speed to engine "idle"
TOP TUBE PERFORMANCE

RCA Announces a new, comprehensive Line of Mobile Communications Tubes for 6-Cell Storage-Battery Operation... in automotive, aircraft, marine, and industrial equipment

AGAIN, RCA IS FIRST—with a line of mobile communications tubes that will insure reliable service in mobile equipment operating with a terminal supply voltage ranging all the way from 12 to 15 volts (they will take momentary excursions from 11 to 16 volts)!

Here is a line of tubes that takes the extra plate and screen dissipation at "cruising" speeds—and yet delivers satisfactory performance at engine "idle". Specially designed and controlled 13.5-volt heaters safely withstand the charge and discharge voltages of 12-volt electrical systems. In addition they are designed to withstand intermittent heater-cycling tests of 2000 cycles minimum, at high heater voltage. Each tube type is subjected during manufacture to rigid tests for heater-cathode leakage, interelectrode leakage, elevated-heater-voltage life performance, and intermittent shorts.

There is a new RCA mobile type for every tube function in your transceiver design. Study the block diagram on the right—check the list for the types you need.

NOTICE TO DESIGNERS OF MOBILE RADIO EQUIPMENT!

Your RCA Field Representative can discuss applications of the new RCA Mobile line immediately. Call him at the RCA Field Office nearest you. For technical data on these tubes, write RCA Commercial Engineering, Section H 35-Q, Harrison, N.J.

RCA ®

RADIO CORPORATION OF AMERICA
Electron Tube Division Harrison, N. J.

RCA-7054—Power Pentode. For class C rf power amplifier, oscillato frequency multiplier, up to 40 Mc. Also for modulator, af power amp fier.

RCA-7055—Twin Diode. For low-current rectifier, detector, speec clipper.

RCA-7056—Sharp-Cutoff Pentode. For if amplifier and rf amplifier to 45 Mc.

RCA-7057—Medium-Mμ Twin Triode. For rf amplifier in cascode-ty circuits up to 200 Mc.

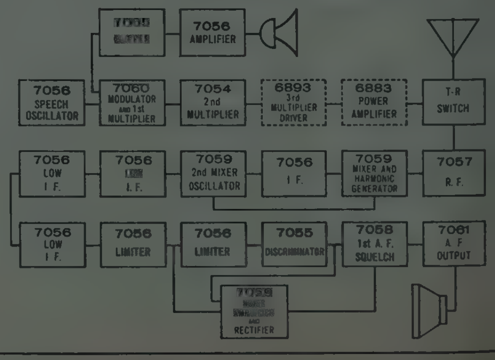
RCA-7058—High-Mμ Twin Triode. For phase-inverter, resistanc coupled amplifier, low-frequency oscillator.

RCA-7059—Medium-Mμ Triode—Sharp-Cutoff Pentode. For oscillat mixer at if frequencies up to 40 Mc. Triode unit also useful for oscillator, and—connected as diode—for high-perveance rectifier noise-squelch circuits.

RCA-7060—Medium-Mμ Triode—Power Pentode. Triode useful for actance modulator; pentode as Class C rf power amplifier, frequen multiplier, up to 40 Mc.

RCA-7061—Beam Power Tube. For af power amplifier.

Tube line-up for typical Mobile Transceiver... using RCA 13.5-volt Heater-Cathode Tubes

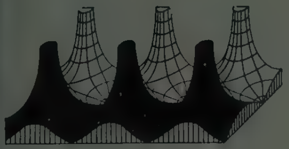

7055 CLIPPER
7056 AMPLIFIER
7056 SPEECH OSCILLATOR
7060 MODULATOR AND 1st MULTIPLIER
7054 2nd MULTIPLIER
6893 3rd MULTIPLIER DRIVER
6883 POWER AMPLIFIER
T-R SWITCH
7056 LOW I. F.
7056 LOW I. F.
7059 2nd MIXER OSCILLATOR
7056 I. F.
7059 MIXER AND HARMONIC GENERATOR
7057 R. F.
7056 LOW I. F.
7056 LIMITER
7056 LIMITER
7055 DISCRIMINATOR
7058 1st A. F. SQUELCH
7061 A. F OUTPUT
7059 NOISE AMPLIFIER AND RECTIFIER

See the RCA Exhibit at the Wescon Show, Booths 1635—163

August, 1958
Vol. 46 No. 8

Proceedings of the IRE

Poles and Zeros



The "Board". The Board of Directors held its May meeting on the twelfth in Dayton, Ohio, as guests of the Dayton Section and the PGANE Conference. As hosts the Section officers were especially gracious, and the Conference program (yes, we heard one session) was excellent. We continue to be amazed by the breed of efficient conference managers that IRE programs have developed across the country in Region after Region, while still keeping their amateur standing in good order.

As is almost universally true of our out-of-New York meetings, this one succeeded in accomplishing more than seems possible in New York. This does not necessarily mean that all the accomplishments are recorded in the minutes, however, as much of the progress occurs over the orange juice and griddle cakes, across the steak, or in the hospitable gatherings sponsored by the host groups. As is well known, captive audiences have their value and in our case a captive Board closely associating over forty-eight hours or so studies and discusses many problems of present and future not on the meeting agenda.

Over one dinner table (we had shrimp) the subject of the operations of the Professional Group on Education was discussed, and agreement reached that its purposes might best be served by deliberate study of the *details* of educational problems, rather than by abstract discussion of educational philosophies. At another gathering the National Convention of this year and several problems growing out of it were reviewed, not as subjects requiring action but for guidance in future years.

A prominent point in the meeting itself was the amount of time devoted to Regional Directors' reports, reports of visits, Section problems, finances, events, people, or needed action, giving the Directors a montage of your Section ideas and operations. Included were news of impending new Sections, creation of the South Carolina Section as the 98th, student activities, and discussion of the need for some revision of Regions in order to allow adequate coverage and promotion by the Directors in their Regions.

Again recognizing that the IRE is international in scope, the Board assigned to the Senior Past President in any year the responsibility for coordinating and fostering the activities of our Sections not now included within the boundaries of the eight Regions, from Tel Aviv to Tokyo. The Editor hopes that this may ultimately repay some of the hospitality given the Senior^2 Past President and the Senior^{-2} Past President on their recent trips abroad.

WESCON Again. Once more it is time for the second major IRE event of the year, WESCON, in Los Angeles on August 19–23. The Editor visited his first WESCON in 1953, when it frankly still retained some of the atmosphere which went with its rented circus tent. He must now truthfully admit that WESCON has eliminated the circus, shown fantastic development and reached a state of maturity exceeded only by the New York Convention. Certainly the combination of West Coast electronic industry, Section virility, and Hollywood showmanship is well worth a trip to see, and with a chance to absorb a little missile, UHF, or computer technology on the side. Wishwewergoinagin!

Transactions, Anyone? The editorial matter served to the readers of Professional Group Transactions in the last month seems even a little more diversified than usual, and usual has lately been quite a spread. Note that *Scanning the* Transactions in this issue shows coverage from push-button education (pills, not yet) to medical electronics, heat transfer simulators to conductive ceramics, and from industrial electronics to unmanned space ships for orbiting the moon. Such is the timeliness and diversity of material available through the Transactions to members of the Professional Groups, now numbering 70,565.

We have previously pointed to the fantastic breadth of the field being enveloped and encompassed by today's electronic engineers and the *Scanning the* Transactions page confirms this. Conversely, we can remember when *radio* was not so comprehensive, ceramic materials were used to hang up antennas and were the concern of the ceramic engineer, when heat transfer was what the mechanical engineer had not provided when the plate dripped, when a millisecond was fast, when sidebands were mathematical fiction, when industrial control designers would not tolerate the hint that there was a better way than a contactor, or that a vacuum tube could be trusted to do tomorrow what it had done today, and space ships were out of this world.

Yes, and we can also remember when electronics was concerned with conduction of electrons through gas or space.

—J.D.R.

Glenn A. Fowler

Director, 1958-1959

Glenn A. Fowler was born at Fresno, Calif., on June 1, 1918. He attended the University of California at Berkeley and obtained the Bachelor's degree in electrical engineering in 1941.

From May, 1941 to December, 1943, Mr. Fowler was a member of the staff at the Radiation Laboratory of Massachusetts Institute of Technology, where he engaged in the development of microwave radar systems. The headquarters of the Army Air Forces then utilized his services as a consultant from December, 1943 to November, 1945 in connection with Air Force airborne radar systems. In May, 1945 he undertook a special assignment at the first atomic bomb test site at Los Alamos, N. M. From that date to November, 1949, he was a member of the staff of Los Alamos Scientific Laboratories and worked at their established field test facilities at Albuquerque, N. M., and Salton Sea, Calif.

When Sandia Corporation was formed in November, 1949, he became its Director of Field Testing and Director of Electronics. He is now Sandia's Vice-President in Charge of Research.

Mr. Fowler, a member of Tau Beta Pi and Eta Kappa Nu, also holds membership in the AIEE. He is a past chairman of the Albuquerque-Los Alamos IRE Section, and a member of the IRE Appointments and Editorial Reviewers Committees. He joined the IRE as an Associate Member, and in 1948 he became a Senior Member.

Scanning the Issue

Batteries (Morehouse, *et al.*, p. 1462)—The PROCEEDINGS presents this month an invited review paper on a subject that is three times as old as radio itself. Despite its venerable age the battery nonetheless represents a field that is currently the center of a surprising amount of important activity. Starting from Volta's discovery of the galvanic cell in 1800, the battery industry has steadily grown to where today it is a husky half-billion dollar industry. Of the many users of batteries, none has a more vital interest in them than the radio engineer. Among all the components he deals with, few can exert such a direct and controlling influence on the design and application of the equipment he builds. His needs, in turn, have been instrumental in greatly stimulating research and development of new and improved types of batteries, especially in the last 15 years. Readers will find in this paper a thorough, yet compact, review of the various types of batteries, how they work, and where they are used. The discussion includes recently developed nuclear and solar-energy power sources as well as the more conventional electrochemical types, and is backed up by an excellent bibliography of over 100 references on the subject.

The Resnatron As a 200-MC Power Amplifier (Tucker, *et al.*, p. 1483)—The tube described in this paper boasts a mighty 3.5 million watts pulsed peak power output at 200 megacycles. It stands 15 feet high, weighs $2\frac{1}{2}$ tons, and its filament draws a mere 7000 amperes. The tube is called a resnatron, which denotes a type of tetrode in which the cavities and tuners are located inside the tube envelope instead of outside. The resnatron was first developed 20 years ago and has an established reputation as a high power tube. Although this type of tube and its operating principles are well known, the development reported here is of more than usual interest because it represents a spectacular jump to megawatt power levels in a frequency range too low to be served by klystrons. While the tube was developed for a very special application—a linear proton accelerator—the problems encountered and techniques used to achieve such a high power output will be of direct interest to designers of high power tubes of all types, as well as of broad interest to systems engineers in general.

Atmospheric Effects on VHF and UHF Propagation (Millman, p. 1492)—The recent advent of earth satellites, guided missiles, and very long range radars has focused considerable attention on the effects of the atmosphere on the propagation of radio waves. Propagation irregularities which formerly were a matter of only academic interest have now become important practical factors in the performance of new long-range systems. For example, it is unlikely that until recently anyone was at all interested in whether the atmosphere would introduce errors in Doppler frequency velocity measurements of objects hundreds of miles away. Yet, in addition to Doppler errors, the ionosphere and troposphere cause changes in the direction of radio waves, time delays, polarization rotations, and attenuation. This paper gives a timely compilation of pertinent theories and data regarding all these effects and presents them in the form of curves and equations which are readily applicable to practical situations.

Atmospheric Noise Interference to Medium Wave Broadcasting (Aiya, p. 1502)—This is one of a series of papers by the same author which investigate various types of electrical discharges associated with thunderstorms and the resulting interference effects they produce. It is a companion to a paper that appeared here last March which dealt with interference in the short wave band. The present paper is concerned with the broadcast band. It differs from the earlier work in that the discharge that gives rise to noise in the broadcast band differs from the one responsible for noise in the short wave band. For example, it is found that lightning discharges within a cloud, which make up 90 per cent of the discharges in a typical storm, do not radiate any significant power below 2.5 megacycles. Thus in the broadcast band, atmospheric interference is due entirely to cloud-to-ground and cloud-to-air discharges, which account for only 10 per cent of the total number of discharges. This study provides a good physical picture and quantitative description of the main source of interference to commercial radio broadcasting.

Suppression of Undesired Radiation of Directional HF Antennas and Associated Feed Lines (Brueckmann, p. 1510)—Many old timers, and perhaps some young timers, too, who find contemporary papers "too mathematical" will have little complaint with this paper which does not contain a single equation. Instead it gives a down-to-earth engineering discussion of the factors responsible for antenna radiation in undesired directions and radiation from balanced open-wire antenna feed lines, and how these causes of interference can be minimized. The discussion is concerned primarily with long range point-to-point communication systems in the 5 to 25-megacycle range, as typified by transoceanic radio stations. In addition to providing broad practical guide lines to good antenna design, two specific developments of interest are reported. One is a novel antenna composed of an array of radiators which form the shape of a giant tapered horn 850 feet long, 560 feet high, and 250 feet wide at the mouth. This antenna has the distinction of outperforming the rhombic antenna, which has been the mainstay of long-range radio stations for a good 30 years. The other development is a wide-band matching transformer which makes feasible the use of coaxial cable in place of open wire feed lines to reduce undesired radiation.

Optimum Noise Performance of Linear Amplifiers (Haus and Adler, p. 1517)—This paper introduces an important new measure of the noise performance of any given type of linear amplifier. This measure takes into account not only the impedance of the source connected to amplifier input and the noise figure of the amplifier, but also the gain of the amplifier stage. By taking gain into account it is able to deal with the case where feedback is applied to an amplifier, a situation in which former measures of noise performance broke down. This new measure of noise thus makes it possible to specify the best noise performance achievable with any type of amplifier. Perhaps the most important property established by the new noise measure is the fact that a cascade of amplifiers of different types cannot have an excess noise figure at high gain that is better than that obtained with amplifiers of the "best" noise class alone.

Scanning the TRANSACTIONS appears on page 1545.

* * *

Batteries*

C. K. MOREHOUSE†, R. GLICKSMAN†, AND G. S. LOZIER†

> The following paper is one of a planned series of invited papers, in which men of recognized standing will review recent developments in, and the present status of, various fields in which noteworthy progress has been made.—*The Editor*

Summary—**A review is given of the chemical compositions, structures, performance characteristics, and applications of various primary and secondary batteries. Both batteries produced presently, and those in the development stages are included.**

The following primary batteries have been discussed: dry, solid-electrolyte, wet, reserve, fuel, and EMF standards. The secondary battery section covers a review of lead-acid, nickel-iron, nickel-cadmium, zinc-silver oxide, and cadmium-silver oxide batteries.

Also included is a review of the various nuclear batteries and solar converters showing the relationship to each other and the electrochemical batteries.

I. Introduction

THE battery industry dates back to Volta's discovery of the galvanic cell in 1800. Prior to the development of the dynamo, batteries were the only practical source of continuous electric current. Although they were replaced as a primary power source toward the end of the nineteenth century, there has been a growing demand for small portable power supplies, resulting in a continued growth in the battery industry through the years. In 1957 about 500 million dollars worth of batteries were produced in the United States alone.

During the first part of the twentieth century, storage batteries for automobiles and dry cells for flashlights were the familiar types. World War II brought a sudden demand for new batteries that greatly stimulated research and development. This led to improved types for existing applications, as well as new batteries to meet new service requirements. Although many of these new batteries may never appear in the civilian market, they nevertheless are important both technically and to our national defense.

Along with new electrochemical batteries, which use chemical energy as their energy source, several new portable power supplies have been developed which use nuclear or solar energy as their energy sources. These devices as yet are not major competitors to the conventional batteries, but are finding some use in specialized applications.

In this paper a review is given of the structures, performance characteristics, and applications of the various electrochemical power supplies. This includes those commercially available, and the important types under development. For completeness, the various nuclear and solar batteries are included and compared with the conventional electrochemical types.

II. Direct Conversion of Chemical Energy into Electrical Energy

Electrochemical processes are the most efficient known for the conversion of one form of energy into usable electrical energy. Batteries, of which a number of different types are produced commercially, are examples of devices which use these processes to convert stored chemical energy directly into electrical energy. They are generally classified into two groups: 1) primary and 2) secondary batteries. The distinction between the two groups is based on the nature of the chemical reactions. Primary batteries are discarded when sufficient electrical energy can no longer be obtained from them (*e.g.*, Leclanché flashlight batteries). Secondary batteries, on the other hand, convert chemical energy into electrical energy by chemical reactions that are essentially reversible. Thus, by passing the current in the reverse direction to that during discharge, the chemicals are restored to their original state (*e.g.*, lead-acid secondary battery).

A battery, of either primary or secondary type, consists of two or more cells connected in either a series, parallel, or series-parallel arrangement to provide different voltages and currents. The cell which is the unit part of the battery consists of five essential components. These are:

Anode—the negative electrode from which electrons flow into the external circuit. Chemically, anodes are reducing agents, characterized by the ease with which they give up electrons and go into solution, forming positive ions.

Cathode—the positive electrode into which electrons flow from the external circuit. Chemically, cathode materials are oxidizing agents, characterized by the ease with which they accept electrons. In so doing, they are reduced to a lower oxidation state.

Electrolyte—a solution that permits ionic conduction between the anode and cathode.

Separator—an inert, porous insulating medium that physically separates the anode and cathode, while permitting the movement of ions in solution between the electrodes.

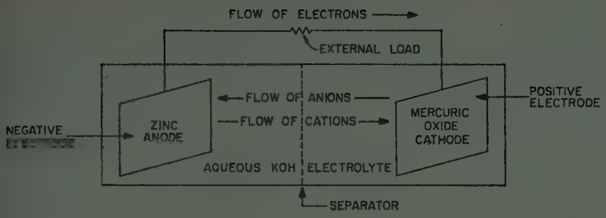
Seal—means for preventing loss of the electrolyte and water, while permitting gas to escape.

A schematic diagram in Fig. 1 illustrates the electrode processes which occur when electrical energy is with-

---

* Original manuscript received by the IRE, April 17, 1958.

† RCA Laboratories, Princeton, N. J.



Anode Reaction: (Oxidation) $\text{Zn} + 2\text{OH}^- = \text{Zn(OH)}_2 + 2e^-$

$\hookrightarrow \text{ZnO} + \text{H}_2\text{O}$

Cathode Reaction: (Reduction) $\text{HgO}+\text{H}_2\text{O}+2e^-=\text{Hg}+2\text{OH}^-$

Overall Energy Producing Cell Reaction: $\text{Zn}+\text{HgO}=\text{ZnO}+\text{Hg}$

Fig. 1—Electrode reactions and relative flow of electrons and ions during the discharge of a zinc-mercuric oxide dry cell.

drawn from a zinc-mercuric oxide dry cell. Although the chemical reactions vary for each electrochemical cell, the principles are the same for all types.

The theoretical energy that can be obtained from an electrochemical cell of either primary or secondary type is derived from the chemical reactions that occur at the anode and cathode. For example, the chemical reaction which takes place in a zinc-mercuric oxide dry cell is,

$$\text{Zn} + \text{HgO} = \text{Hg} + \text{ZnO}. \tag{1}$$

The free energy change (ΔF) for this reaction is related to the potential of this couple by the following equation,

$$-\Delta F = nFE, \tag{2}$$

where F is the Faraday (96,494 coulombs), n the electron change, and E the electromotive force of the cell. From the free energies of the substances involved, the EMF of this cell is calculated to be 1.34 volts.

The EMF of the cell can also be obtained from the half-cell electrode reactions which are shown below along with their reversible potentials (E°):

$$\text{Anode: } \text{Zn}+2\text{OH}^-=\text{Zn(OH)}_2+2e^- \quad E^\circ=1.245 \tag{3}$$

$$\text{Cathode: } \text{HgO}+\text{H}_2\text{O}+2e^-=\text{Hg}+2\text{OH}^- \quad E^\circ=0.098. \tag{4}$$

The potentials at the anode and cathode are also dependent upon the type and concentration of electrolyte (in accordance with the Nernst equation). For the zinc-mercuric oxide cell with a potassium hydroxide electrolyte, the anode potential (E_A) is 1.317 volts, while the cathode potential (E_c) is $+0.028$ volt.

The EMF of this cell is equal to the sum of the anode and cathode potentials, *i.e.*,

$$E_{\text{cell}} = 1.317 + 0.023 = 1.34 \text{ volts}$$

and the over-all reaction (1) is obtained by taking the sum of the two half-cell reactions, (3) and (4). Thus, from a knowledge of the reversible half-cell potentials, reactions, and electrolyte, the theoretical potential of any electrochemical couple can be calculated.

Table I and Table II (p. 1464) list pertinent data [1], [2] for various anode and cathode materials now used in electrochemical cells. Included in these tables are the theoretical ampere-minute capacities of the various anode and cathode materials which give the theoretical quantity of electricity available from one gram of material. These values, which are calculated on the basis of Faraday's law, are directly proportional to the number of Faradays per mole involved in the electrochemical reaction and inversely proportional to the molecular weight and volume of the material.

In coupling any of these anode and cathode materials to make an electrochemical cell, it must be kept in mind that they should be compatible with the particular electrolyte used, the extent of compatibility depending upon the particular application. For example, the use of a cathode such as mercuric oxide and an anode such as magnesium in acid solutions would not be advisable due to the high solubility of mercuric oxide and high rate of corrosion of magnesium in acidic electrolytes.

In practice, most electrodes operate at potentials lower than their reversible values, due to polarization effects encountered under load conditions, while their electrode efficiencies also vary with current drain. In addition to the energy losses due to the irreversibility of the electrode reactions, additional losses are encountered in cells due to ohmic IR losses (*i.e.*, resistance of cell components) or deleterious side effects which limit the amount of active material available for the energy producing chemical reactions. Examples of these are the corrosion of metal anodes, or the solubility of the cathode material in the electrolyte, resulting in diffusion to and reaction with the anode material.

Although the principles discussed previously are common to all electrochemical cells, the technical problems will vary from one type of cell to another, due to the use of different electrode materials, constructions, and applications. In the following parts the various primary and secondary cells are discussed in greater detail.

A. Primary Cells

Primary cells include several types designed for different applications. These are subdivided as follows: 1) dry, 2) solid-electrolyte, 3) wet, 4) reserve, 5) fuel, and 6) standard cells.

1) Dry Cells: The name, dry cells, is a misnomer as the cells actually contain an aqueous electrolyte which is immobilized, and does not spill out when the cells are inverted. Three types of dry cells are presently produced in quantity in this country. The chemical composition of these cells, together with those of the important new cells now under development, are listed in Table III (p. 1465). Also included in the table are the energy producing chemical reactions, approximate average operating voltages, and watt-minute capacities as measured on a light-drain application. In addition, pertinent references are cited in case the reader is interested in more detailed information.

a) Leclanché cells: Approximately 90 per cent of the dry cells produced annually in the United States are zinc-manganese dioxide cells, commonly called Leclanché cells after their inventor [22]. The original cells made by Leclanché in 1868 had a spillable electrolyte.

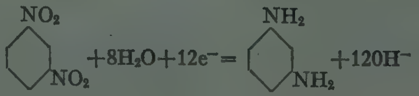
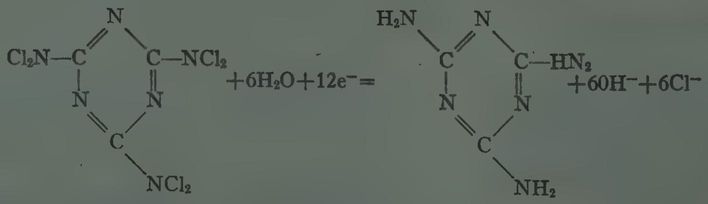
TABLE I

Half-Cell Reactions, Potentials, and Capacity Data for Various Anode Materials

Anode Material	Half-Cell Reaction	Half-Cell Potential (volts)		Theoretical Ampere-Minute Capacity	
		E°_{Acid}	E°_{Base}	per gram	per cm³
Sodium	$Na=Na^++e^-$	2.71		69.9	67.8
Magnesium	$Mg+2OH^-=Mg(OH)_2+2e^-$		2.67	132.2	230
Magnesium	$Mg=Mg^{++}+2e^-$	2.37		132.2	230
Aluminum	$Al=Al^{+++}+3e^-$	1.67		178.9	483
Zinc	$Zn+2OH^-=Zn(OH)_2+2e^-$		1.245	49.2	351
Zinc	$Zn=Zn^{++}+2e^-$	0.76		49.2	351
Indium	$In+3OH^-=In(OH)_3+3e^-$		1.0	42.0	307
Cadmium	$Cd+2OH^-=Cd(OH)_2+2e^-$		0.81	28.8	248
Iron	$Fe+2OH^-=Fe(OH)_2+2e^-$		0.88	57.6	455
Lead	$Pb=Pb^{++}+2e^-$	0.13		15.6	176
Lead	$Pb+SO_4^{=}=PbSO_4+2e^-$	0.37		15.6	176
Hydrogen	$H_2=2H^++2e^-$	0.00		1596	112
Hydrogen	$H_2+2OH^-=2H_2O+2e^-$		0.828	1596	112

TABLE II

Half-Cell Reactions, Potentials, and Capacity Data for Various Cathode Materials

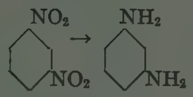
Anode Materials	Half-Cell Reaction	Half-Cell Potential (volts)		Theoretical Ampere-Minute Capacity	
		E°_{Acid}	E°_{Base}	Per Gram	Per cm³
Manganese Dioxide	$MnO_2+4H^++2e^-=Mn^{++}+2H_2O$	+1.23		37.4	188.1
Manganese Dioxide	$MnO_2+H_2O+e^-=\frac{1}{2}\ Mn_2O_3\cdot H_2O+OH^-$		+0.17	18.5	93.1
Mercuric Oxide	$HgO+H_2O+2e^-=Hg+2OH^-$		+0.098	14.8	165
Lead Dioxide	$PbO_2+SO_4^{=}+4H^++2e^-=PbSO_4+2H_2O$	+1.685		13.4	125
Lead Dioxide	$PbO_2+H_2O+2e^-=PbO+2OH^-$		+0.247	13.4	125
Nickel Dioxide	$NiO_2+2H_2O+2e^-=Ni(OH)_2+2OH^-$		+0.49	32	~110
Silver (II) Oxide	$2AgO+H_2O+2e^-=Ag_2O+2OH^-$		+0.570	26.0*	193*
Silver (I) Oxide	$Ag_2O+H_2O+2e^-=2Ag+2OH^-$		+0.345	13.9	99.2
Silver Chloride	$AgCl+e^-=Ag+Cl^-$	+0.222		11.2	62.5
Cupric Oxide	$2CuO+H_2O+2e^-=Cu_2O+2OH^-$		−0.159	40.4*	261*
Cuprous Oxide	$Cu_2O+H_2O+2e^-=2Cu+2OH^-$		−0.357	20.2	121
Cuprous Chloride	$CuCl+e^-=Cu+Cl^-$	+0.137		16.7	58.9
Bismuth Oxide	$Bi_2O_3+3H_2O+6e^-=2Bi+6OH^-$		−0.457	20.7	184
Oxygen	$O_2+2H_2O+4e^-=4OH^-$		+0.40	201	229
Chlorine	$Cl_2+2e^-=2Cl^-$	+1.360		45.3	68.0
m-Dinitrobenzene			−0.15†	114.9	181.5
Hexachloremelamine	 Cl₂N—C N C—NCl₂ N N C NCl₂ +6H₂O+12e⁻= H₂N N C C—HN₂ N N C NH₂ +60H⁻+6Cl⁻		+1.00†	58.0	~92.8

* Calculated on the basis of 2-electron change per mole of oxide.

† Potentials reported are operating potentials, *i.e.*, under load conditions.

TABLE III

CHEMICAL COMPOSITION AND PERFORMANCE CHARACTERISTICS OF VARIOUS DRY CELLS

Type	Cell Components			Energy Producing Reaction
	Anode	Electrolyte	Cathode	
Commercial cells				
Leclanché	Zn	$NH_4Cl\text{-}ZnCl_2$	MnO_2	$Zn+2MnO_2 \rightarrow ZnO \cdot Mn_2O_3$*
Zinc-Mercuric Oxide (RM)	Zn	KOH	HgO	$Zn+HgO \rightarrow Hg+ZnO$
Alkaline Zinc-Manganese Dioxide (Crown)	Zn	NaOH	MnO_2	$Zn+2MnO_2 \rightarrow Mn_2O_3+ZnO$
New cell developments				
Magnesium-Manganese Dioxide	Mg	$MgBr_2$	MnO_2	$Mg+H_2O+2MnO_2 \rightarrow Mn_2O_3+Mg(OH)_2$
Magnesium-Organic	Mg	$MgBr_2$	M-Dinitro-benzene, etc.†	$6Mg+8H_2O+$  $+6Mg(OH)_2$
Magnesium-Bismuth Oxide	Mg	$MgBr_2$	Bi_2O_3	$3Mg+3H_2O+Bi_2O_3 \rightarrow 2Bi+3Mg(OH)_2$
Air	Zn	NaOH	O_2(Air)	$Zn+\frac{1}{2}O_2 \rightarrow ZnO$
Indium	In	KOH	HgO	$2In+3HgO \rightarrow 3Hg+In_2O_3$
Aluminum	Al	$AlCl_3\text{-}(NH_4)_2Cr_2O_7$	MnO_2	$2Al+3H_2O+6MnO_2 \rightarrow 3Mn_2O_3+2Al(OH)_3$

Type	Open Circuit Voltage (volts)	Average Operating Voltage‡ (volts)	Capacity Watt-Minutes		References
			Per Gram of Cell‡	Per cm³ of Cell‡	
Commercial cells					
Leclanché	1.5–1.65	1.25	4.0	6.1	[3], [4]
Zinc-Mercuric Oxide (RM)	1.34	1.30	7	32	[3], [5]–[8]
Alkaline Zinc-Manganese Dioxide (Crown)	1.52	1.15	2.6	8.1	[9]
New cell developments					
Magnesium-Manganese Dioxide	1.8–2.0	1.4–1.5	5.8	12	[10]–[12]
Magnesium-Organic	1.65	1.15	8.5	12	[13]–[16]
Magnesium-Bismuth Oxide	1.6	1.03	6.2	12	[17]
Air	1.4–1.5	1.2–1.3	—	—	[3], [18], [19]
Indium	1.15	1.05	—	—	[20]
Aluminum	1.7	1.3	—	—	[21]

* Example of one of several reactions which can occur in a Leclanché dry cell.
† Example of one of many organic cathode materials which can be used.
‡ Approximate results for a light drain application.

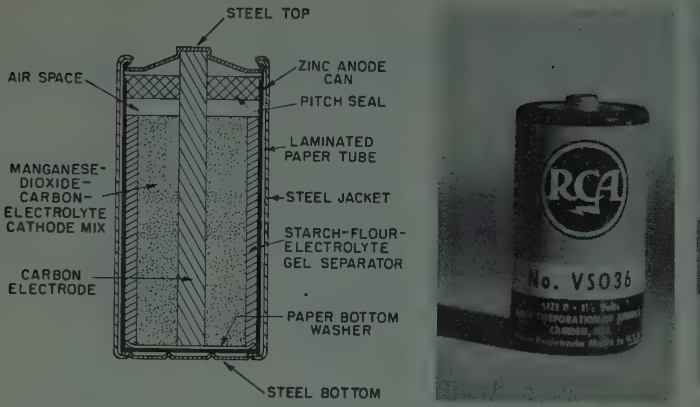

STEEL TOP
AIR SPACE
ZINC ANODE CAN
PITCH SEAL
LAMINATED PAPER TUBE
MANGANESE-DIOXIDE-CARBON-ELECTROLYTE CATHODE MIX
STEEL JACKET
STARCH-FLOUR-ELECTROLYTE GEL SEPARATOR
CARBON ELECTRODE
PAPER BOTTOM WASHER
STEEL BOTTOM
RCA
No. VS036

Fig. 2—Cross section of a typical cylindrical flashlight dry cell.

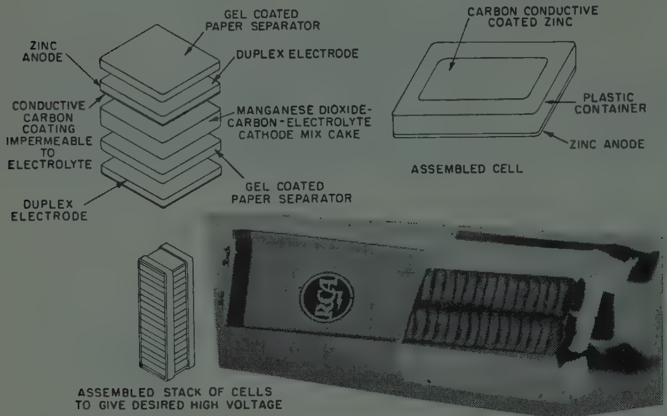

GEL COATED PAPER SEPARATOR
ZINC ANODE
DUPLEX ELECTRODE
CONDUCTIVE CARBON COATING IMPERMEABLE TO ELECTROLYTE
MANGANESE DIOXIDE-CARBON-ELECTROLYTE CATHODE MIX CAKE
GEL COATED PAPER SEPARATOR
DUPLEX ELECTRODE
CARBON CONDUCTIVE COATED ZINC
PLASTIC CONTAINER
ZINC ANODE
ASSEMBLED CELL
ASSEMBLED STACK OF CELLS TO GIVE DESIRED HIGH VOLTAGE
RCA

Fig. 3—A typical Leclanché flat-cell construction.

RCA
IGNITION DRY

Fig. 4—Various sizes of dry cells. Back row: Leclanché. Middle row: zinc-mercuric oxide (RM). Front row: alkaline zinc-manganese dioxide (crown).

In spite of their large size they were capable of supplying only small currents. At the end of the nineteenth century, improved cell designs [23], [24] appeared with an immobilized electrolyte, thus marking the approximate beginning of the dry cell industry. Today, in the United States, two billion cells are produced annually as compared to 34 million cells produced in 1909 [25].

Along with this growth, there also has been a continued improvement in performance. For example, over the past thirty years performance gains ranging up to 400 per cent have been reported [26], [27]. These gains, which have been the result of a continued research and development effort by the industry, have been due to changes in cell design, elimination of harmful impurities, and the use of higher grade materials which allow for the more efficient conversion of the available chemical energy into usable electrical energy.

Two basic cell designs of the Leclanché type are presently being manufactured. Cross sections of cylindrical, and of flat or layer-built constructions, are shown in Figs. 2 and 3. These two basic designs are made in a number of different sizes, a few of which are illustrated in Fig. 4.

The majority of cylindrical cells contain an amalgamated zinc can which is the negative electrode and functions as the anode and container of the cell. The cylindrical core (positive electrode) is formed from a mixture of manganese dioxide and carbon which is wet with electrolyte. A carbon rod which acts as the positive terminal is inserted in the center of the cathode mix. The two electrodes are separated by a starch-flour gel also containing some electrolyte.

Some manufacturers use a "metal-clad" construction [28] in which the entire cell, surrounded by an insulating jacket, is encased in a steel tube. This metal construction has the feature of retarding cell leakage caused by zinc can perforation. Others have used modified starch paste separators [29] to make a more leak-resistant cell. In this latter case the starch does not undergo decomposition during cell discharge, and any liquid which escapes from the cell can be readily absorbed in a suitable paper jacket.

Although most of the cylindrical cells are of the previously described construction, one manufacturer makes an "inside-out" cell [30]. This cell has the terminals reversed with the negative zinc anode in the center of the cell. The advantages claimed for this cell are better utilization of zinc and freedom from leakage due to zinc can perforation.

The need for space economy in the high-voltage batteries for radio "B" application has led to the design of flat cells [31]–[33]. The first flat cell battery known as the "minimax" construction [31] was developed by the National Carbon Company. The essential feature of these designs is a duplex electrode, consisting of a flat sheet of zinc, on one side of which is an adherent conductive coating impermeable to the electrolyte composed of carbon mixed with a plastic binder. One side of the zinc serves as the anode of one cell, while the conductive-coated side serves as the positive electrode of the adjacent cell and makes contact with the manganese dioxide cathode. A gel coated paper separates the two cell electrodes. The cells, which are contained in a plastic envelope, as illustrated, are stacked to give the desired voltage, taped to maintain low-contact resistance, and sealed by dipping in wax to prevent moisture loss.

Although the control of all cell components is important from the standpoint of performance, the manganese dioxide cathode is generally considered as the limiting component of Leclanché cells for many applications. For example, the efficiency of the manganese dioxide electrode varies from less than 10 per cent on very heavy current drain applications (D-size flashlight cells discharged continuously at drains greater than 0.5 ampere) to over 90 per cent on light drain applications (radio B).

At present most of the manganese dioxide used in dry cells comes from the African Gold Coast. There is, however, a definite trend to use manganese dioxides which are prepared synthetically by chemical or electrolytic processes as the natural ore supply becomes depleted, and the demand increases for high-cell capacity per unit of weight and volume. The more costly synthetic materials differ from the naturally occurring manganese dioxide in crystal structure, particle size, impurities, and chemical activity. They are used at present in cells designed for high-current drain usage, such as encountered in many industrial and military applications.

The open circuit voltage of Leclanché dry cells ranges between 1.5 and 1.6 volts depending upon the electrolyte composition and type of manganese dioxide used. It decreases about 0.0004 volt per °C over the temperature range of 25°C to −20°C. The ampere-hour and watt-hour capacity or hours of service to the specified end voltages are dependent upon the size of cell, and the rate at which energy is withdrawn from the cell. The lower the rate, the more efficient conversion of the available chemical energy into usable electrical energy. Intermittent type of service is generally preferred, especially for heavy current drain usage. As a rough rule, heavy drain may be defined as meaning any drain which results in a service life of 10 hours or less. In addition, cell capacity is affected by temperature of operation, falling off with decreasing temperature. The cells become inoperative at about −30°C due to freezing of the electrolyte. The low-temperature performance of Leclanché dry cells can be considerably improved and their operation extended to below −40°C by changing to an electrolyte with a lower freezing point [34]–[37].

Shelf life is dependent on quality of manufacturer, cell size, cell formulation, and temperature of storage. In general, for any given manufacturer, the smaller the cell size, the shorter shelf life. Storage temperature has a marked effect on shelf life, the lower the temperature, the longer the shelf life. For example, A-size cells stored for 24 months at 21.1°C gave only 50 per cent of their initial capacity, whereas 70 per cent and 90 per cent capacity retention were obtained from comparable cells stored at 7.2°C and −17.8°C, respectively [27].

The large number of cell sizes and applications has led to the adoption of a considerable number of tests, each intended to simulate some kind of service, as for example, flashlights, portable radios, hearing aids, telephones, or military services. Some of these tests are described in American Standards Specification C 18.1-1954 [38], or the Signal Corps Specification [39]. Most tests involve discharging the cell or battery through a constant resistance simulating the current drain required to power the particular equipment. For example, a flashlight test consists in discharging a single cell through a $2\frac{1}{4}$-ohm resistance until it reaches 0.65 volt. This simulates the drain on each cell in a two cell flashlight containing a 0.5-ampere bulb. As most dry cells are not subjected to exhaustive continuous service, the majority of the standard tests are intermittent in nature varying from a few minutes of discharge a day to continuous usage. For example, general purpose flashlight cell tests require that the cell be discharged for five consecutive minutes a day, whereas radio battery tests require that the cells or batteries be discharged two or four hours a day. Capacity data, which should be gathered at 21.1°C, are generally reported as hours or minutes of service to specified end voltages. Typical discharge curves and capacity data for Leclanché dry cells compared with other dry cells are shown in Fig. 6 and Fig. 9 through Fig. 11.

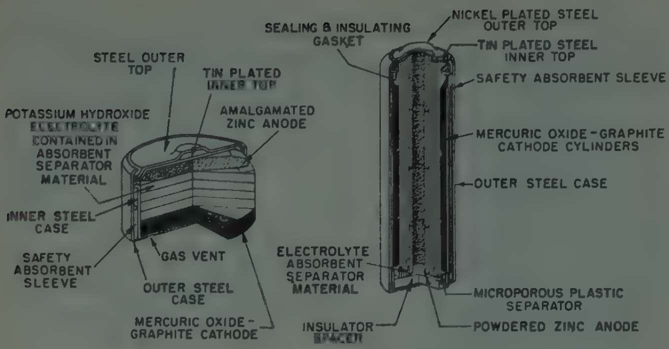
b) Zinc-mercuric oxide cells: The alkaline zinc-mercuric oxide system was first suggested by Clarke [40] in 1884. Although there were a number of additional attempts made over the years [41]–[44] to design a practical cell using this system, it was not until early in World War II that a commercially usable mercuric oxide dry cell was invented by Ruben [5].

Cells of this general classification contain an amalgamated zinc anode in the form of either a finely divided powder or a coiled corrugated strip. The cathode consists of a mixture of red mercuric oxide with about 5 per cent graphite molded under pressure into a steel cup or pressed as a discrete part and assembled into the cell, depending on the type of cell produced. The electrolyte is an aqueous potassium hydroxide solution containing zinc oxide, and the separator is composed of two materials: a cellulosic material to immobilize the electrolyte, and a barrier material such as microporous plastic interposed between the cathode and the cellulosic material. Two typical constructions which are commercially available are shown in Fig. 5.

The open circuit voltage of mercuric oxide cells is 1.345 volts which is in close agreement with the thermodynamically calculated value for this electrochemical system. These cells have a flat voltage-time discharge curve operating for most of their discharge life between 1.34 and 1.24 volts, depending upon the current drain; the lighter the current drain, the nearer the closed circuit voltage of the cell is to its open circuit voltage. A typical discharge curve for this cell compared with a comparable size Leclanché cell is shown in Fig. 6.

Compared with the Leclanché cell, zinc-mercuric oxide dry cells have several desirable features, namely: 1) a more constant voltage during discharge life, 2) a greater watt-hour capacity per unit of volume and weight, and 3) reportedly better shelf life during storage at elevated temperatures of 45°C and 54.5°C.

In spite of these favorable characteristics, only about 10 per cent of the total dry cells produced annually in this country are of the mercuric oxide type, the reason being the large difference in basic material cost. Mercuric oxide costs approximately six dollars per pound compared to $0.07 a pound for manganese dioxide. Because of this high cost differential, the mercuric oxide cell has not replaced the Leclanché cell to any appreciable extent in sizes larger than the AA-size (volume 0.43 in^3), these sizes are used in the lighting field. For lighting applications the initial cost of the cell or battery


SEALING & INSULATING GASKET
NICKEL PLATED STEEL OUTER TOP
TIN PLATED STEEL INNER TOP
SAFETY ABSORBENT SLEEVE
STEEL OUTER TOP
TIN PLATED INNER TOP
POTASSIUM HYDROXIDE ELECTROLYTE CONTAINED IN ABSORBENT SEPARATOR MATERIAL
AMALGAMATED ZINC ANODE
MERCURIC OXIDE-GRAPHITE CATHODE CYLINDERS
OUTER STEEL CASE
INNER STEEL CASE
SAFETY ABSORBENT SLEEVE
GAS VENT
OUTER STEEL CASE
MERCURIC OXIDE-GRAPHITE CATHODE
ELECTROLYTE ABSORBENT SEPARATOR MATERIAL
INSULATOR SPACER
MICROPOROUS PLASTIC SEPARATOR
POWDERED ZINC ANODE

(a) RM-1 (b) CYLINDERICAL RM-502R

Fig. 5—Cross sections of two typical zinc-mercuric oxide dry cells (manufactured by P. R. Mallory Co.)

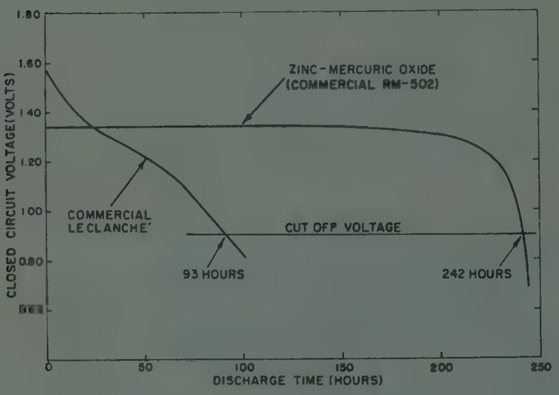


Fig. 6—AA-size penlight dry cells discharged continuously through 150-ohm resistances (simulates current drain encountered in a transistor-operated receiver).

is undoubtedly a more important factor to the consumer than cost or volume per unit of service.

Mercuric oxide cells, however, find use in both military and civilian applications, where capacity per unit of volume and constancy of voltage are important factors. Some of these applications are: hearing aids, small portable radios, portable communication equipment, electrical test apparatus, scientific instruments, and as reference potentials in instruments where the extreme precision of a Weston Standard cell is not required.

Zinc-mercuric oxide dry cells are made in a variety of cell sizes, some of which are illustrated in Fig. 4.

c) Alkaline zinc-manganese dioxide cells: A third type, known as "crown cells" because of their crown cap construction [9], is produced in small quantities in this country. These small cells which are similar in construction to the zinc-mercuric oxide cells are composed of a manganese dioxide cathode, an aqueous sodium hydroxide electrolyte, and an amalgamated powdered zinc anode. They have an open circuit potential of 1.52 volts and are most suitable for low-drain applications. Whereas these cells do not give as high a capacity as comparable size mercuric oxide cells, they have a cost advantage in that they contain a cheaper cathode material. Improved performance with a subsequent increase in material cost can be obtained by adding mercuric oxide to the manganese dioxide cathode mix.

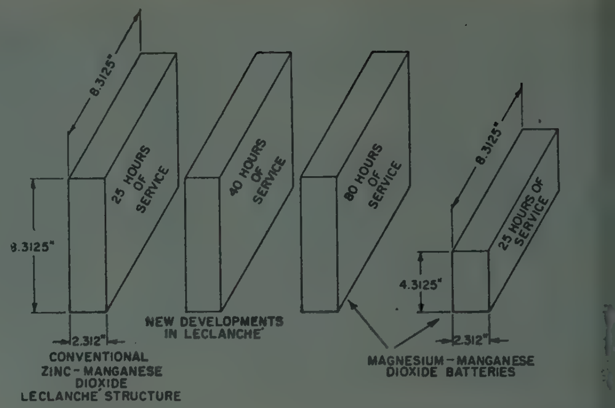

8.3125"
25 HOURS OF SERVICE
40 HOURS OF SERVICE
80 HOURS OF SERVICE
8.3125"
25 HOURS OF SERVICE
8.3125"
4.3125"
2.312"
2.312"
CONVENTIONAL ZINC-MANGANESE DIOXIDE LECLANCHE' STRUCTURE
NEW DEVELOPMENTS IN LECLANCHE'
MAGNESIUM-MANGANESE DIOXIDE BATTERIES

Fig. 7—Relative performance of conventional BA279/U Leclanch as compared to magnesium-manganese dioxide dry cells batterie (BA279/U batteries are used in the Signal Corps handy-talki AN/PRC-8, 9, 10 transcievers).

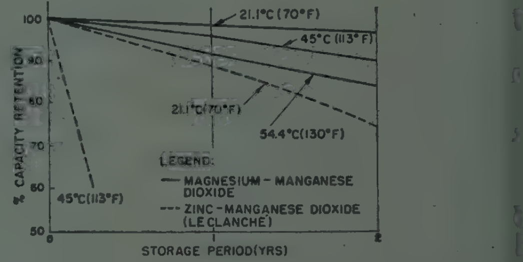


Fig. 8—Shelf life at various storage temperatures of magnesium manganese dioxide flashlight size cells compared with comparabl size commercial Lechlanché dry cells.

d) New dry cell developments: The zinc-manganese dioxide Leclanché cell has been the dominant dry cel system for over 50 years despite the existence of othe theoretically more attractive anode (*e.g.*, Mg, Al) an cathode (*e.g.*, O_2, organic) materials. However, it was no until recently that some of these materials becam readily available, and that the electrochemical characteristics were sufficiently understood to enable practica cells to be designed.

In addition, new applications have appeared whic require performance characteristics different from thos of the conventional cells. This has resulted in severa new developments using materials which, although no as attractive on the basis of available energy per unit o weight and volume, have other desirable propertie which are important to meet the new requirements.

The status of these new dry cells is briefly reviewed i the following paragraphs.

Magnesium cells: Theoretically magnesium is a mor attractive anode material for primary cells than zin having a considerably higher reversible electrode potential, and more than twice the ampere-hour capacit per unit of weight. Many attempts [45] have been mad over the years to design a practical magnesium electrochemical cell, but it was not until the last ten years tha several significant developments have been reporte These have involved the coupling of a magnesium anod and an aqueous magnesium bromide electrolyte wit such cathode materials as manganese dioxide, bismut

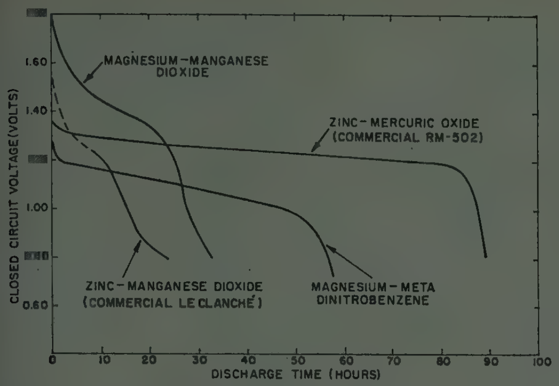


Fig. 9—AA-size penlight dry cells discharged continuously through 50-ohm resistances (simulates current drain encountered in some portable radios).

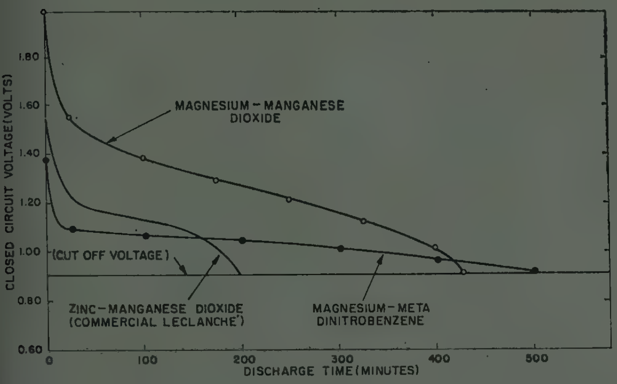


Fig. 10—C-size flashlight dry cells discharged intermittently through 4-ohm resistances (4 minutes per hour, 8 hours per day) (simulates use with 0.25-ampere flashlight bulb).

oxide, and a number of organic compounds. Each of these new dry cells has some desirable characteristics, and offers the possibility of replacing the conventional dry cells for certain applications.

The magnesium-manganese dioxide cells described by Kirk, Fry, and George [10]–[12] are constructed similarly to the Leclanché using an impact extruded magnesium alloy can. They have a sloping voltage-time discharge curve as does the Leclanché cell, but operate at 0.1 to 0.3 volt higher. These cells give double the watt-hour capacity of zinc-Leclanché dry cells on a number of tests corresponding to flashlight, lantern, and radio application. Some of the performance gains on military tests [46] are illustrated in Fig. 7. In addition to the capacity advantages, the magnesium-manganese dioxide cells are reported [46] to have a better shelf life than the Leclanché dry cells, especially at the elevated storage temperatures (Fig. 8).

The second important magnesium cell development involves the use of organic cathode materials, such as aromatic nitro and C-nitroso compounds [13]–[16]. Many of these compounds have from 5–8 times the theoretical ampere-minute capacity of manganese dioxide and mercuric oxide, materials presently used in commercial cells. In addition, the chemical energy derived from these materials can be efficiently converted into

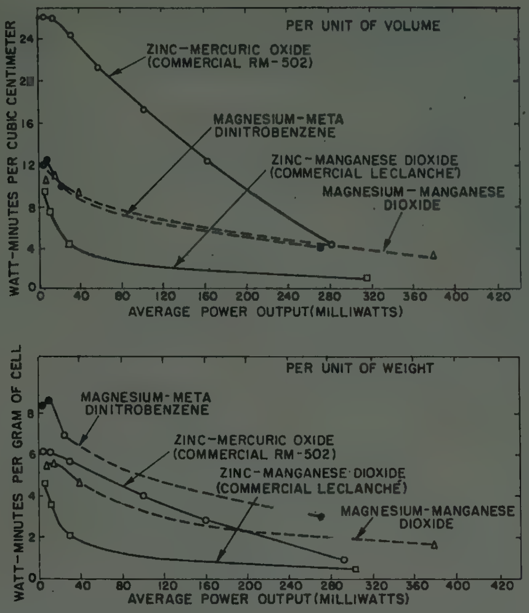


Fig. 11—AA-size dry cells discharged continuously through various resistances (watt-minute capacity and average power output computed to 0.90 volt end voltage).

usable electrical energy. The operating voltage characteristics of the magnesium-organic cells depend upon the structure and types of organic compounds used, but, in general, they have a more constant voltage-time discharge curve than the manganese dioxide cells. For example, the magnesium-meta dinitrobenzene cells operate between 1.00 and 1.20 volts for most of the discharge time, while corresponding cells containing *p*-nitrosodimethylaniline as the cathode material operate between 1.2 and 1.4 volts. Typical discharge curves for AA-penlight and C-size organic cells compared with the Leclanché and magnesium-manganese dioxide cells are shown in Figs. 9 and 10. The C-size cells were discharged intermittently through a 4-ohm resistance simulating flashlight use, while the AA-size cells were discharged continuously through 50-ohm resistances to simulate current drains encountered in portable radio applications. Additional data at various power output levels, showing the relationships between the three cells on the basis of watt-minute capacity per unit of volume and weight at various power output levels, are shown in Fig. 11. These data illustrate the superiority of both types of magnesium cells over the Leclanché on the basis of watt-hour capacity per unit of weight and volume. The desirable features of the organic cells are their constant operating voltage characteristics and their ability to give more hours of service to 1.00 and 0.90 volts than the two manganese dioxide cells.

The organic cell development, aside from the favorable theoretical and proven performance gains, has an additional important feature. It opens the door to a vast supply of new materials, many of which are relatively cheap, and nonstrategic, thus offering the promise of eliminating the country's dependence on foreign ore deposits. Further research in this area should result in superior compounds and a better understanding of their efficient utilization.

Another development is the use of a bismuth oxide cathode with a magnesium anode [17]. These cells, because of the cost relationships between bismuth oxide, manganese dioxide, and mercuric oxide, would be expected to be more expensive than the Leclanché, but cheaper than the zinc-mercuric oxide cells. They operate 0.2 to 0.3 volt lower than the zinc-mercuric oxide cells, but have flat voltage-time discharge characteristics similar to this cell. The bismuth oxide cell should not be considered as competitive with the Leclanché for lighting applications, but with further development might compete with the more costly mercuric oxide cell.

With the proven performance gains for these three magnesium dry cells, one might wonder why they have not reached the commercial market. The organic and bismuth oxide cells are relatively new, but the magnesium-manganese dioxide cell has been under extensive research and development for over ten years. There are several technical problems associated with the use of magnesium anodes. These are: cost, "delayed action," high impedance, and loss in capacity on light intermittent tests. These problems are gradually being solved, and it is predicted that magnesium dry cells will achieve commercial significance in the near future.

Air dry cells: Air cells are a class of cells which utilize the oxygen of the air as the cathode component. Several cells of this type have appeared on the market over the years [18], [19]. The most successful of these, the primary wet cell, is discussed in Section II-A, 3.

About 1950 the first air cell of the dry type was produced for a time in this country. These cells contain a zinc anode, an aqueous sodium hydroxide electrolyte, and a special porous water-repellent carbon positive electrode. The carbon electrode is sufficiently porous to permit adequate access of air, and the occlusion of enough oxygen to maintain the intended rates of discharge. They are designed to operate at current drains as high as 0.06 amperes, and for nominal use have an average voltage of about 1.05 volts.

The air dry cells as assembled at the factory are sealed to prevent desiccation during storage. The seal is broken before use to allow oxygen of the air into the porous carbon electrode. For short continuous operation, these cells perform satisfactorily, but for long intermittent types of service, they are subject to drying-out resulting in loss of capacity. It is for this reason that these dry cells have not found wide application. If a membrane can be found which will allow for the efficient transfer of oxygen into the cell without the transfer of water vapor out of the cell, air dry cells should find some commercial application.

Aluminum and indium dry cells: Two other dry cell developments which should be mentioned are the aluminum-manganese dioxide and the indium-mercuric oxide dry cells.

The first is an aluminum counterpart to the Leclanché and magnesium-manganese dioxide cells. It consists of an Alclad aluminum anode can, an aqueous aluminum chloride electrolyte, and a manganese dioxide cathode. Ammonium dichromate is added to the electrolyte to inhibit the corrosion of the aluminum [21]. These cells operate about 0.1 volt higher than the Leclanché with the same sloping voltage discharge characteristics. More research and development is needed on this cell to improve its performance on intermittent tests, as well as to ascertain the shelf life characteristics.

The other development might be considered as an indium counterpart to the zinc-mercuric oxide cell, differing from the latter in the use of an indium anode in place of zinc [20]. The feature of these small cells is that they can be hermetically sealed as the indium anode is more resistant to corrosion then zinc, and thus would liberate less gas. They have a flat voltage-time discharge curve comparable to the zinc-mercuric oxide cell, but have an operating voltage 0.2–0.3 volt lower. These cells were designed specifically for use in an electronic wrist watch. They are more expensive and give less capacity than the zinc-mercuric oxide cell.

2) Solid Electrolyte Cells: Solid electrolyte cells are distinguished from other primary cells using liquid electrolytes, as they are composed of solid materials only. A cell of this type, containing a silver anode, a solid silver iodide electrolyte, and an iodine cathode, has an open-circuit voltage of 0.69 volt with a short-circuit current of 20 μa per square centimeter of electrode area [47]. The silver iodide electrolyte acts as an ionic conductor, permitting the diffusion of silver ions through its crystal lattice.

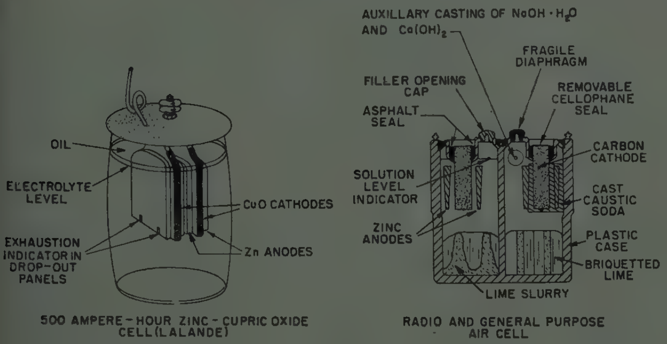
The most outstanding feature of the solid electrolyte cells is their potentially long shelf life. This is in contrast to cells with liquid electrolytes, in which the shelf life is limited by the reaction of the electrodes with the electrolyte and by the evaporation of the electrolyte itself. Because of their expected 10–20 year shelf life, the solid electrolyte cells are ideal for use in military and other equipment that may be stored for years in a standby condition.

A typical commercial solid electrolyte battery consists of 127 extremely thin cells of the composition $Ag/AgBr/CuBr_2$, which are stacked in series to produce a potential of 95 volts. This battery which weighs 4.2 grams (0.15 ounce) and measures 0.86 cm (0.34 inch) in diameter and 2.5 cm (0.97 inch) in length, has an available charge of 1 coulomb and furnishes a flash current of 8 μa. It can be applied as a power source for radiation warning devices and monitoring instruments, and as a charger for low-leakage capacitors. Other potential applications include use as a bias supply for high-impedance circuits, and furnishing low currents to circuits employing electrometer tubes or ionization devices.

Another type of primary cell designed for these applications is the wax electrolyte cell which, like the solid electrolyte cells, has a predicted long shelf life and sustains low currents only. The cell consists of a zinc anode, a manganese dioxide cathode, and an electrolyte of zinc chloride dissolved in a solid wax of polyethylene glycol [48]. A typical 25-cell wax electrolyte battery, which weighs 0.2 ounce is 0.3 inch in length and 0.5 inch in diameter, has an electromotive force of 37.5 volts and a short-circuit current of 3×10^{-7} amperes at ordinary temperature.

3) *Wet Cells:* Two types of primary wet cells are produced in this country, the zinc-cupric oxide Lalande [3], [18], [19] and the zinc-air cell [3], [18]. These cells find applications where a large capacity, moderately large currents at constant voltage, and long life are the dominant service requirements. Mine, highway, railway, and marine signaling installations, telephone and telegraph circuits, and radio "A" are examples of equipment that are powered by these cells.

The Lalande cell consists of a zinc anode, a caustic soda electrolyte, and a cupric oxide cathode contained in a glass jar. Various electrode shapes and spacings are used depending upon the manufacturer and intended application. A typical construction is shown in Fig. 12. The cells are usually shipped dry, the electrolyte being added prior to usage, and a film of oil added to the top of the electrolyte to prevent evaporation of water and adsorption of carbon dioxide into the solution. In general, Lalande cells are designed to give 500–1000-ampere-hour capacities, and operate between 0.5 and 0.7 volt at current drains as high as 15 amperes. They give capacities of about 2.5 watt-minutes per cm³ and 1.85 watt-minutes per gram.



500 AMPERE-HOUR ZINC-CUPRIC OXIDE CELL (LALANDE)

RADIO AND GENERAL PURPOSE AIR CELL

Fig. 12—Cross sections of typical zinc-cupric oxide and zinc-air wet cells. (Schumacher and Heise [18].)

The air cell, which is considered as a replacement for the Lalande cell, differs from the latter in that it contains a porous carbon electrode in place of the cupric oxide. As in the case of the zinc-air dry cell, the porous carbon electrode is designed to absorb oxygen from the air which in turn is reduced in the course of cell discharge. The air cells operate at 1.1–1.2 volts, and have a constant voltage-time discharge curve. Like the Lalande cell, they are designed to be assembled in the field by adding the caustic soda electrolyte. A typical air cell of the Railway type shown in Fig. 12 is designed to operate at continuous drains as high as 2.0 amperes, or 3.0 amperes on intermittent service. These cells give capacities between 7–11 watt-minutes per cm³ and 5-9 watt-minutes per gram.

4) *Reserve Cells:* Reserve batteries, sometimes called "one shot" or "delayed action" batteries are primary cells which are assembled in an inactive state and activated prior to use. They are designed to meet some specific application, usually military, and because of their composition and construction have some inherent advantages over the other conventional primary batteries. Some of these are: more active electrochemical systems may be utilized to obtain a higher energy output per unit of weight and volume, long shelf life with a minimum of maintenance, and high over-all performance reliability.

Stimulated by World War II, the development of reserve batteries has involved a study of various electrochemical systems and procedures for activating the cells or batteries. In general, the important cells can be classified into three groups, a) liquid-activated, b) gas-activated, and c) heat-activated as shown in Table IV (p. 1472). The liquid-activated magnesium-silver chloride, magnesium-cuprous chloride, and zinc-silver oxide cells are the most important, the others being in the development stages or used only to a limited extent.

a) Liquid-activated:

Magnesium-water activated cells: The water-activated cell systems are among the relatively new power sources which have become important to the military since the beginning of World War II. These cells are stored dry in an inactive condition in hermetically sealed containers and are activated by adding water. They have the advantage over other reserve cell systems in that the electrolyte need not be transported with the battery. One disadvantage is the slow activation time requiring several seconds to minutes for complete activation. They find use in powering airborne equipment, signal lights, emergency lighting, lights for floating buoys, radiosonde equipment, and air-sea rescue equipment.

The magnesium-silver chloride and magnesium-cuprous chloride are two types of water-activated cells commercially available. From the performance data listed in Table IV, it is seen that the silver chloride cells operate at higher voltages and have higher capacities than the cuprous chloride cells. The cuprous chloride cells, however, are cheaper. Both of these cell systems have a constant voltage-time discharge curve and the characteristic of evolving heat during cell discharge which makes them applicable for operation at temperatures as low as −54°C, temperatures encountered in meteorological applications. The heat evolved during cell discharge is due mainly to the corrosion of the magnesium, the energy of this reaction being liberated as heat instead of electrical energy. Typical designs of batteries of this type are illustrated in Fig. 13 (p. 1473).

TABLE IV

CHEMICAL COMPOSITION AND PERFORMANCE CHARACTERISTICS OF VARIOUS RESERVE CELLS

Type	Anode	Electrolyte	Cathode	Activating Agent	Energy Producing Reaction
Liquid-Activated Zinc-Silver Oxide	Zn	KOH	AgO	KOH	$Zn+AgO \rightarrow ZnO+Ag$
Zinc-Lead Dioxide	Zn	H_2SO_4	PbO_2	H_2SO_4	$Zn+PbO_2+H_2SO_4+2H^+ \rightarrow Zn^{++}+PbSO_4+2H_2O$
Cadmium-Lead Dioxide	Cd	H_2SO_4	PbO_2	H_2SO_4	$Cd+PbO_2+H_2SO_4+2H^+ \rightarrow Cd^{++}+PbSO_4+2H_2O$
Lead-Lead Dioxide	Pb	H_2SO_4, HBF_4 H_2SiF_6, or $HClO_4$	PbO_2	H_2SO_4, HBF_4 H_2SiF_6, or $HClO_4$	$Pb+PbO_2+2H_2SO_4 \rightarrow 2PbSO_4+2H_2O$ $Pb+PbO_2+4H^+ \rightarrow 2Pb^{++}+2H_2O$
Magnesium-Silver Chloride	Mg	$MgCl_2$	AgCl	H_2O	$Mg+2AgCl \rightarrow MgCl_2+2Ag$
Magnesium-Cuprous Chloride	Mg	$MgCl_2$	CuCl	H_2O	$Mg+2CuCl \rightarrow MgCl_2+2Cu$
Magnesium-Organic-N-halogen	Mg	$MgCl_2$, $MgBr_2$	Organic-N-halogen (e.g. trichloromelamine)	H_2O	$6Mg+6H_2O+2$ trichloromelamine $\rightarrow 2$ melamine $+3Mg(OH)_2+3MgCl_2$
Gas-Activated Zinc-Chlorine	Zn	NH_4Cl-$ZnCl_2$	Cl_2	Cl_2	$Zn+Cl_2 \rightarrow ZnCl_2$
Ammonia Vapor Activated	Mg, Zn	$NH_4SCN^-NH_3$	PbO_2, MnO_2	NH_3	—
Boron Trifluoride	Mg, Al Pb, Zn	HBF_4, HBO_3	PbO_2, MnO_2	BF_3	$Pb+PbO_2+4H^+ \rightarrow 2Pb^{++}+2H_2O$
Heat-Activated	Ca	KCl^-LiCl	$ZnCrO_4$	heat to melt $LiCl^-KCl$	—
	Mg	KCl^-LiCl	Basic $ZnCrO_4$		—
	Ca	KCl^-LiCl	WO_3		

Type	Operating Characteristics of Cells Discharged Under Optimum Conditions			
	Average Operating Voltage (Volts)	Capacity		References
		Watt Minutes per Gram	Watt Minutes per cm^3	
Liquid-Activated Zinc-Silver Oxide	1.4–1.5	6.6–7.4	11.4–13.2	[54], [55]
Zinc-Lead Dioxide	2.1–2.4	3.4	13.9	[56], [57]
Cadmium-Lead Dioxide	1.8–2.1	1.8	4.0	[57], [58]
Lead-Lead Dioxide	1.6–2.1	2.1–2.6	5.5–7.7	[57]
Magnesium-Silver Chloride	1.3–1.6	up to 10.6	up to 29.3	[26], [49]–[51]
Magnesium-Cuprous Chloride	1.1–1.3	2.6–4.0	5.1	[26], [49], [52]
Magnesium-Organic-N-halogen	1.9–2.3	up to 8.0	up to 8.4	[53]
Gas-Activated Zinc-Chlorine	1.3–1.9	—	—	[59], [60]
Ammonia Vapor Activated	—	2.0–2.6	3.7	[61]
Boron Trifluoride	1.6–2.1	—	—	[62]
Heat-Activated	3.28	—	—	[63], [64]
	2.23	—	—	—
	2.48	—	—	—

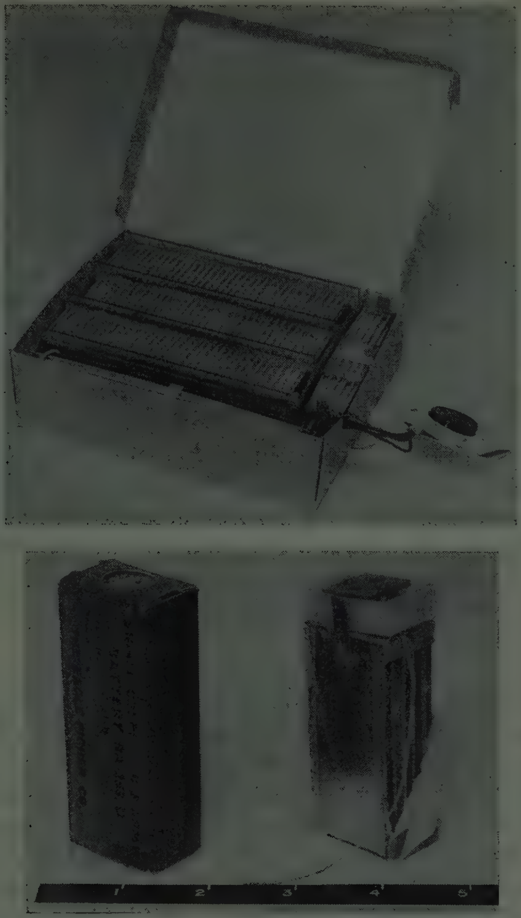


Fig. 13—Magnesium-cuprous chloride water-activated reserve batteries.

An important new water-activated reserve cell system under development utilizes a magnesium anode and organic N-halogen compounds, such as trichloromelamine [53]. The N-halogen compounds are attractive as they operate at 0.6–0.7 volt higher than the silver chloride electrode, approaching the potential of the chlorine electrode. In addition, many of these materials have a greater theoretical ampere-minute capacity per unit of weight than any of the inorganic materials. To date, it has been shown that batteries can be made which will give nearly twice the watt-hour capacity per unit of weight and volume of the magnesium-cuprous chloride battery on certain military tests.

Zinc-silver oxide cells: Zinc-silver oxide reserve cells have been developed to meet the need for high-rate batteries capable of delivering their rated capacities in one to ten minutes. They find application in missiles, radio-controlled model planes and boats, emergency power, etc.

The valuable features of these cells are their high watt-hour capacities per unit of weight and volume and constancy of voltage during discharge at high-power output levels. An example of a typical battery is the Signal Corps BA-467/U which occupies a volume of about 0.16 m^3 (960 inches^3), weighs 22.7 kg (50 pounds) and delivers 180 amperes for 10 minutes at a voltage of 28±2 volts.

These batteries, which are designed primarily for military applications are stored dry and are automatically activated. One activation method is to apply an electric pulse to a squib which ruptures a diaphragm holding back the potassium hydroxide electrolyte. This forces the electrolyte into the battery. Activation times on the order of a few tenths of a second for the battery to reach operating voltage have been attained. In order to achieve operation at low temperatures (−54°C), electric heaters are incorporated in the batteries.

Lead dioxide cells: Several lead dioxide reserve cells [56]–[58] have been described, consisting of a lead dioxide cathode and a zinc, cadmium, or lead anode. These cells which are designed for high rate applications, are activated by adding aqueous solutions of fluoroboric acid, sulfuric acid, or fluorosilicic acid. They have a limited life after activation due to the rapid attack of the zinc and cadmium anodes by the electrolyte. The interest in these cell systems has been due to their superior low-temperature performance without the use of external heaters, and their low cost.

b) Gas-activated cells: Three different gas-activated cells now under development are shown in Table IV. Although they differ from each other in performance characteristics, they have one common feature in that they are activated by adding a gaseous component. In the case of the zinc-chlorine cell, the cell is activated by introducing chlorine into a porous carbon electrode. The chlorine gas is contained under pressure in a cylinder with an electrically operated valve. The other two cells are activated by adding an electrolyte component, such as ammonia or boron trifluoride. Various anode and cathode materials have been investigated for the latter type cells.

These cells are being designed for high rate applications of the type for which the zinc-silver oxide batteries are presently used. The potential advantages of these new systems are high capacity, favorable low temperature characteristics, and low cost.

c) Heat-activated (thermal) cells: In these cells the electrolyte is a nonconductive solid at ordinary temperatures. They are activated by applying heat which melts the solid electrolyte making it conductive and enabling current to be withdrawn from the cells. Calcium and magnesium have been used as anode materials, various metallic chromates and oxides as cathodes, and alkali halides as electrolytes [63], [64]. The favorable features of these cells are: high-operating cell voltages (*e.g.*, over 3.00 volts); ability to withstand high current drains; long shelf life in the inactivated condition; operation over wide temperature range; no maintenance; and ruggedness. These cells have a relatively short operating life which limits their use to specialized military applications requiring a few minutes of service.

5) Fuel Cells: For many years, investigators have been attracted to the problem of converting the energy

TABLE V

REPORTED EFFICIENCIES OF VARIOUS ENERGY CONVERTERS

Energy Source	Conversion Processes	Reported Efficiency (per cent)
Chemical	Electrochemical	90
Chemical, Nuclear, or Solar	Heat→Mechanical (*e.g.*, steam-turbine)	40
Chemical, Nuclear, or Solar	Heat→Thermionic	8
Chemical, Nuclear, or Solar	Heat→Thermoelectric	7
Solar	Photovoltaic	12
Nuclear	Dielectric Charging	1
Nuclear	Contact Potential	0.01
Nuclear	Electron Voltaic	2.5

of fuels directly to electrical energy without passing through the intermediate thermal and mechanical stages. In principle, the conversion of carbonaceous fuels such as coal to electrical energy could be more efficiently carried out in an electrochemical cell than by the conventional steam-turbine cycle, as the efficiency of the latter cycle is limited by more severe thermodynamic restrictions. As seen from the data in Table V, electrochemical processes are the most efficient known for the conversion of chemical energy into electrical energy. Fuel cells are electrochemical cells. They differ from conventional batteries in that the chemicals which enter into the anode and cathode reactions are fed into the electrodes at a rate proportional to the rate at which electrical energy is withdrawn.

Two types of fuel cell systems have been extensively investigated within the past ten years. The first involves the use of carbonaceous fuels, the objective being to efficiently realize the energy that can be derived from coal. In order to avoid some of the difficulties associated with feeding coal directly into a cell, coal is first converted into carbon monoxide or water gas, these gases are fed into the negative electrode of the cell. At the same time, oxygen is fed into the positive electrode, the over-all energy producing cell reaction being $CO + 1/2O_2 \rightarrow CO_2$. It has been reported [65] that cells containing perforated-iron electrodes with a mixed carbonate electrolyte impregnated in a porous magnesia diaphragm can be made to operate continuously for several months at a conversion efficiency of 55 per cent. These cells which were designed to operate at 600°C had an operating potential of 0.8 volt at a current density of 55 ma/cm^2 of electrode surface area. Although this is a remarkable advance, it is still not competitive with the conventional methods for producing large quantities of electrical energy. However, it has been calculated that an over-all efficiency of 75 per cent should be possible if water gas is used in an integrated system and the electrochemical cell operated at a high temperature such that the waste can be utilized to effect the endothermic water gas reaction. If such a goal is realized, and the cells can be shown to operate within a minimum of maintenance, fuel cells of this type will be increasingly important.

The other class of fuel cells utilize hydrogen as the fuel, the over-all energy producing cell reaction being: $2H_2 + O_2 \rightarrow 2H_2O$. Two cells of this type have been reported. Both types use a caustic electrolyte but differ in their electrode composition and operating temperature. The high temperature (200–250°C) cell designed by Bacon and his associates [66] has an operating potential between 0.5 and 1.05 volts at current densities up to 1 ampere/cm^2. It has been claimed that these cells can be operated continuously for several months at an efficiency of 70 per cent giving power outputs ranging up to 22,000 watts/m^3 (6000 watts/foot^3) of cell volume. A cell, developed by National Carbon Company, which operates at room temperature utilizes porous carbon electrodes and gives comparable efficiencies to the Bacon cell.

Although the hydrogen-oxygen cells probably will not compete economically with the large power stations, the advantages of such cells are that they serve as a source of silent power, and give greater watt-hour capacities per unit of weight and volume at higher power rates than the conventional batteries.

6) EMF Standards:

a) Weston cell: The Weston or standard cells, are examples of electrochemical cells which are used as standards of electromotive force. They consist of an amalgamated cadmium anode, an aqueous solution of cadmium sulfate as the electrolyte, and a mercurous sulfate cathode. There are two types, saturated and unsaturated, the terminology referring to the concentration of the cadmium sulfate in the electrolyte. The saturated cells are more constant in EMF, but require careful control of temperature for accurate measurements. These are used primarily as reference standards. The unsaturated cells which are commercially available have a temperature coefficient close to zero, and are suitable for work requiring no greater accuracy than 0.01 per cent. The average EMF of new unsaturated cells is about 1.01916 absolute volts and should not change more than 71 μv per year [67].

Standard cells are delicate instruments made from very high purity chemicals, and should not be subjected to strong light and temperatures above +40°C or below 4°C. They also can be damaged if anything but negligible currents are withdrawn from them.

b) Grid-bias cells: Cells of this type serve as a source of potential rather than of current, finding use in electronic equipment as a bias on the control grid. They are small, hermetically-sealed cells composed of a vanadium pentoxide cathode, a weak-acid electrolyte such as a viscid ammonium glycol borate paste, and either a zinc or cadmium anode. The cadmium cells have an electromotive force of 1.05 volts, and zinc cells 1.2 volts. If properly used, the life of these cells may be 10 years or more without more than a negligible change in EMF [68].

B. Secondary Cells

Secondary or storage cells are electrochemical cells which after discharge can be restored to their original

TABLE VI

Chemical Composition and Performance Characteristics of Various Secondary Batteries

Type	Anode	Electro-lyte	Cathode	Current Producing Reaction Discharge → Charge ←	Average Operating Voltage on Light Drains (Volts)	Capacity on Light Drains*		References
						Whr/lb	Whr/in³	
Lead-Acid	Pb	H_2SO_4	PbO_2	$Pb+PbO_2+2H_2SO_4 \rightleftharpoons 2PbSO_4+2H_2O$	1.95–2.05	16–20	1.5 –2.1	[26], [69]–[71]
Nickel-Iron (Edison)	Fe	KOH	$Ni(OH)_3$, Ni_2O_3, & NiO_2	$Fe+NiO_2 \rightleftharpoons FeO+NiO$	1.10–1.30	12–13	0.98–1.05	[26], [69]–[71], [78]
Nickel-Cadmium (Junger)	Cd	KOH	$Ni(OH)_3$, Ni_2O_3, & NiO_2	$Cd+NiO_2 \rightleftharpoons CdO+NiO$	1.10–1.30	10–12	0.75–0.95	[26], [69]–[71], [79]–[82]
Zinc-Silver	Zn	KOH	AgO	$Zn+AgO+H_2O \rightleftharpoons Ag+Zn(OH)_2$	1.40–1.50	50–55	3.1 –3.6	[26], [69], [83]–[85]
Cadmium-Silver	Cd	KOH	AgO	$Cd+AgO \rightleftharpoons Ag+CdO$	1.05–1.10	~33	~2.7	[26], [86]
Lead-Silver Oxide	Pb	KOH	Ag_2O	$Pb+Ag_2O \rightleftharpoons PbO+2Ag$	0.80–0.85	13.6	1.8	[87]
Cadmium-Mercuric (Oxide)	Cd	KOH	HgO	$Cd+HgO \rightleftharpoons CdO+Hg$	0.9	—	—	[88]

* These data were calculated from large capacity batteries under optimum conditions.

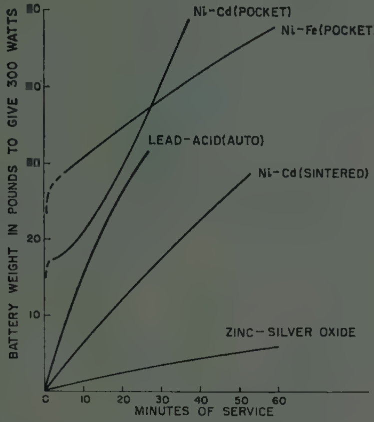


Fig. 14—Relative performance of various secondary systems of special construction designed to deliver 300 watts for a specified time interval.

chemical state by passing the current in the reverse direction. Although they have the same set of basic components as primary cells, the anodes and cathodes of secondary cells have a more stringent requirement, in that the electrode reactions have to be reversible. This requirement immediately limits the number of electrode materials available for secondary cells. At present, lead, cadmium, iron, and zinc anode materials, and lead dioxide, nickel dioxide, and silver oxide cathode materials are the only ones used in commercial secondary cells.

The secondary battery business dates back to Planté's discovery of the lead-acid system in 1860. Over the years there has been a continuous growth in this business, reaching a total of about 300 million dollars in 1956 in the United States alone. They are used for a wide variety of applications ranging from megawatt power supplies for submarines to small milliwatt power supplies for portable radios.

At present five types of batteries are produced commercially. The chemical composition and some of their performance characteristics are listed in Table VI, and Fig. 14. Each are discussed in greater detail in the following paragraphs.

1) Lead-Acid Batteries: Lead-acid secondary batteries, the most important of the five classes, are made in a variety of sizes and shapes for many applications. Three major types are produced, automotive, motive, and stationary [69]–[71]. The applications for which each are designed and their performance characteristics are listed in Table VII and Fig. 15. Whereas the basic energy-producing chemical reaction is the same for all lead-acid cells, these types differ from each other in construction and performance characteristics.

Automotive batteries [72], the most important class in terms of total value of product and general availability, are made in a limited number of standard sizes on automatic equipment with emphasis on low cost. They are designed to furnish high currents (200 to 300 amperes for a 6-volt system) for a few seconds or minutes over a wide range of temperatures. These requirements have led to a thin plate construction (Fig. 16). The electrodes are comprised of grids cast from high-purity lead containing about 10 per cent antimony which are filled with a paste consisting of a mix of lead oxide, water, and sulphuric acid. The paste of the negative plates contains about 1 per cent of "expander" to improve the high rate discharge and low-temperature characteristics. The expander contains two important ingredients, barium sulfate on which lead sulfate can crystallize, and an organic material, such as the derivative of the lignin fraction of wood, which prevents lead sulfate from crystallizing on the sponge lead surface. No expander is used in the positive plates. After the plates have been formed, dried, and assembled, they are immersed in a weak sulphuric acid solution and charged, the lead oxide of the negative plate being converted to sponge lead, and lead dioxide being formed at the positive plates. Acid-resistant porous wood or microporous rubber separators are generally used to separate the anodes and cathodes from each other. Performance data for a typi-

TABLE VII

Typical Applications and Performance Characteristics of Various Secondary Batteries

Type	Application	Life Characteristics		Charge Retention	References
		Cycle Service Life	Float Charging Life		
Lead Acid					
Automotive	High currents for a few seconds or minutes: engine cranking	250–400 cycles	Up to 4 years in automotive service with good care	20% to 30% drop per month	[69]–[72]
Motive	Discharge rate of 3 to 10 hours with nearly complete discharge: electric trucks, air conditioning and lighting of railroad cars	3–6 years (see text)	—	—	[69]–[71], [73]
Stationary					
Lead-Antimony grid	Designed for long service life, in particular on float type charging: emergency power, railway signals, telephone exchanges	6–8 years	14 years	30% drop per month	[69]–[71], [74]
Lead-calcium grid		Not determined	25 years (estimated)	6% drop per month	[74], [76]
Planté Positive		10–14 years	25 years	—	[74]
Low Discharge	Specially designed stationary for low discharge rates and low self-discharge rates: recording, warning, and control devices: industrial and laboratory instruments	10–20 cycles with 6 months to a year between cycles	20 years	15% drop per year	[75]
Electrolyte Retaining	Designed to have nonspillable electrolyte for portable high-rate power in place of dry cells: radio, photographic flash units, guided missiles	200–300 cycles	—	30% drop per month	[77]
Nickel-Iron (Edison)	Heavy duty industrial and railway applications:	1800 cycles	7–12 years heavy Industrial; 14–25 years standby	25% to 35% drop per month	[69]–[71], [78]
Nickel-Cadmium					
Pocket Plate	General purpose cell with wide applicability where mechanical and electrical abuse and long life are important factors	As good as sintered plate if not better	25 years	20% to 40% drop per year	[69]–[71], [79]
Sintered Plate	High rate and low temperature	Several thousand cycles*	20–25 years (estimated)	Less than 50% drop per year	[69]–[71], [80]–[82]
Zinc-Silver Oxide					
High Rate	Discharge rates of 1 minute to 30 minutes	10–20 cycles over 3–6 months	—	—	[69], [83]–[85]
Medium Rate	Discharge rates of 30 minutes to 5 hours	40–50 cycles over 6–9 months	—	20% to 30% drop per year	
Low Rate (1 hour and over)	Discharge rates over 1 hour	150 cycles over a year; 300 cycles with special construction	—	—	
Cadmium-Silver Oxide	Low-rate and long-life applications	600–700 cycles, 3000 cycles on a 40% discharge	Estimated to be good	Estimated as good as zinc-silver oxide	[86]

* [illegible] claims 5000 cycles

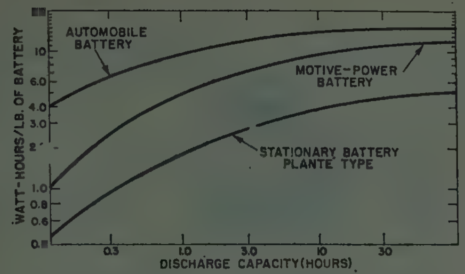


Fig. 15—Power output of various types of lead-acid batteries. (Courtesy of *Encyclopaedia Britannica.*)

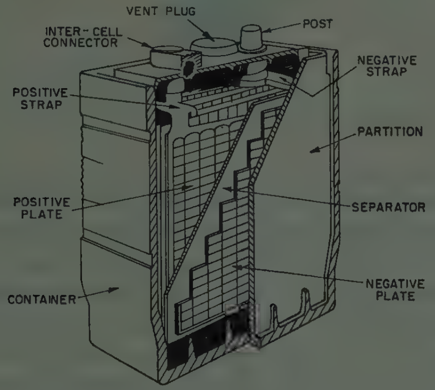
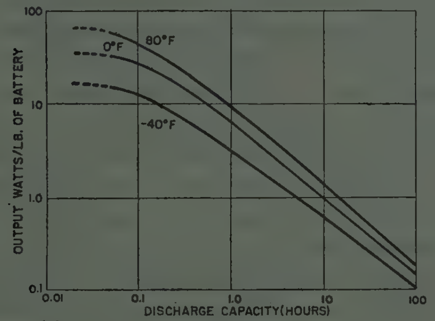
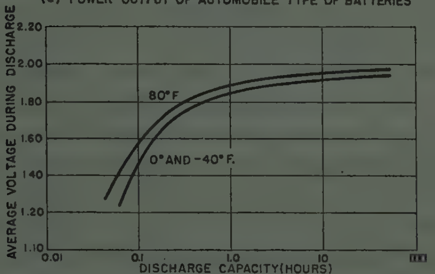


Fig. 16—Cutaway of automotive battery showing the pasted plate construction. (Courtesy of Electric Storage Battery Company.)



(a) POWER OUTPUT OF AUTOMOBILE TYPE OF BATTERIES



(b) AVERAGE VOLTAGE DURING DISCHARGE OF AUTOMOBILE BATTERIES

Fig. 17—Performance data for a typical automotive battery. (Willihnganz [72].)

cal automotive battery are shown in Fig. 17. It should be noted that the main effect of temperature is on the current output and not the voltage.

The second major class of lead-acid batteries is used for motive-power service [73]. They are required to supply power for three to ten hours, and are designed to withstand frequent deep discharges instead of remaining almost fully charged as in the case of automotive batteries. The negative plates of motive batteries although thicker are similar to automotive batteries. The most important difference between the two types is that the positive plates are protected to prevent loss of active material which would otherwise occur in batteries that are alternatively charged and discharged. One method is to incorporate the active material in slotted cylindrical sleeves which have antimonial lead or silver-lead spines in the center to allow for the passage of electrons to the active material. A positive plate consists of an assembly of these tubes as shown in Fig. 18. Another design comprises the use of thicker pasted plates with several layers of strong separator material to prevent the loss of active material during use. These changes in positive plate construction along with the use of thicker grids have led to batteries which give three to six years of service in applications where automotive batteries would last less than six months. However, they are more expensive than comparable size automotive batteries.

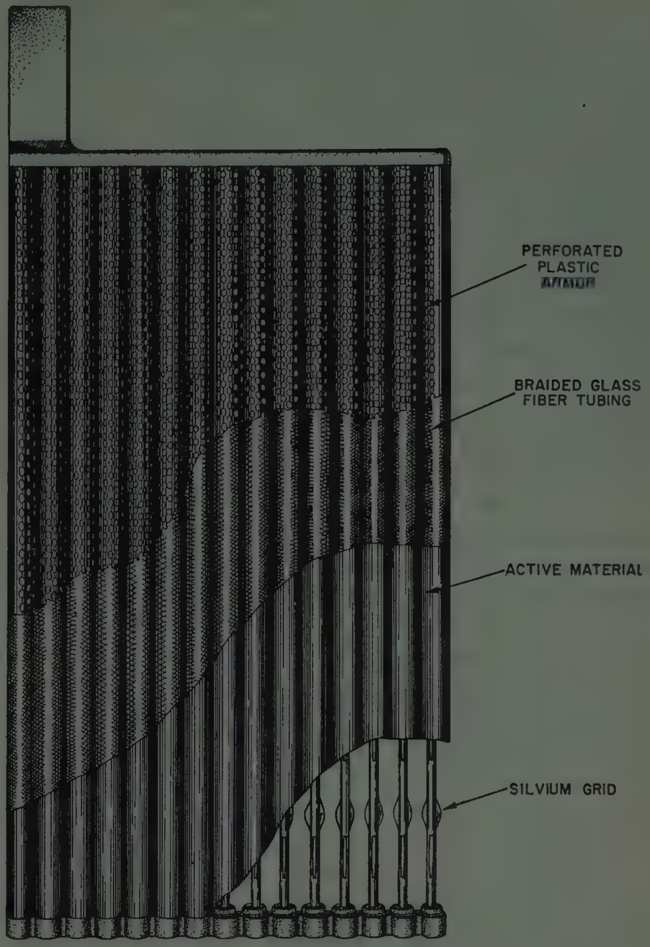


Fig. 18—Positive plate of an exide-ironclad battery. (Courtesy of Electric Storage Battery Company.)

Stationary batteries [74], [75]; unlike the automotive and motive types, are designed for long life applications which do not require the mechanical ruggedness or high current output. Low self-discharge, stability, and high efficiency are the important features. Most of the stationary batteries use the pasted positive plate construction similar to the motive battery. A Planté positive plate type construction is also used. In this case, the active material is derived from the plate itself. In addition to a different positive plate construction, the grid material and design are also constructed differently to decrease the self-discharge rate encountered in the other two battery types. This has been accomplished by using grid materials, such as pure lead or a lead-calcium alloy [76], in place of the lead-antimony alloy. Antimony, which is needed for structural reasons, causes a high self-discharge rate. Antimony also causes gassing at lower charging voltages.

A fourth class of lead-acid batteries are those which have been designed with an electrolyte-retaining separator to prevent loss of electrolyte when the batteries are inverted [77]. These batteries are generally smaller in size than the other types and are designed for portable high-rate power applications for which the conventional dry cells would not be suitable.

2) *Nickel-Iron* (*Edison*) *Batteries:* The nickel-iron-alkaline batteries [69]–[71], [78] as they exist today are essentially the same as discovered by Edison around 1900 and marketed in 1908. The negative electrode consists of pockets of active material grouped together to form a plate, while the positive plate is an assembly of perforated nickel tubes filled with nickel hydroxide and nickel. A cutaway view of the nickel-iron cell is given in Fig. 19. These batteries find their widest use in heavy duty industrial and railway applications, *e.g.*, 1 to 8-hour discharge rates.

The nickel-iron cell on a five hour rate has a slightly greater capacity on a weight basis while occupying a little larger volume than a lead-acid motive-power battery.

A second interesting property of this battery is that its ampere-hour capacity remains close to its rated capacity at high discharge rates. However, at high discharge rates the voltage of nickel-iron batteries drops considerably and hence is not recommended for automotive applications.

These batteries have other advantages in that the are mechanically strong and resist electrochemical abuse. For example, they may be overcharged, and completely discharged for long periods of time. In addition, they operate at higher temperatures and have a longer life than the lead-acid batteries.

There are several disadvantages to the use of these batteries. One is their poor low-temperature performance. Also, they consume more water, develop more heat, and are more expensive than lead-acid batteries. Also, their charge retention is poor; a typical battery after one month storage loses approximately 42 per cent of its initial capacity.

3) *Nickel-Cadmium Batteries:* The nickel-cadmium battery [69], [70] discovered by Junger and Berg about 1900 is closely related to the nickel-iron Edison battery. Both are mechanically rugged and will withstand electrochemical abuse in that they can be overcharged, overdischarged, or stand idle in a discharged condition. The nickel-cadmium battery differs from the Edison battery in the use of cadmium anodes in place of iron. Although the nickel-cadmium batteries operate at slightly lower voltages than the nickel-iron batteries, they show very little self-discharge. They can be trickle-charged, and when standing idle they evolve practically no gas, so that for some purposes they can be hermetically sealed. The nickel-cadmium batteries can be operated over a temperature range of −54°C (−65°F) to 82°C (180°F) and they are characterized by an excellent service life under both cycle and float operation. Initially, they are more expensive than comparable lead-acid batteries, which has limited their use for some applications.

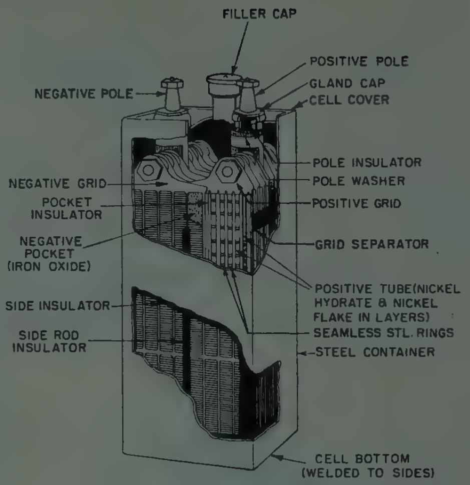


Fig. 19—Cutaway view of nickel-iron cell. (Anderson [78].)

The two nickel-cadmium cell constructions in use are the pocket type [79], similar to the nickel-iron construction, and the sintered-plate construction [80]–[82]. The sintered-plate construction differs from the pocket type in the method of support. Plates are made from nickel powder which is molded into shape and heated at an elevated temperature in a nonoxidizing atmosphere. This gives a strong, porous plate which contains about 80 per cent pore volume. The active material is impregnated in the pores of these plates by soaking them in a solution of nickel salts to make positive plates, and a solution of cadmium salts to make negative plates.

The sintered-plate design, because of the thinner plate construction and larger electrode surface area, offers advantages over the pocket-type construction in that they operate at higher current drains and are more efficient at low temperatures. For example, specially designed sintered plate batteries can be discharged and charged at −54°C. These properties are desirable for automotive use, and except for cost, the nickel-cadmium sintered-plate batteries are competitive

TABLE VIII
PERFORMANCE CHARACTERISTICS OF VARIOUS NUCLEAR BATTERIES

Type	Energy Source (millicuries)	Conversion Process	Voltage (volts)	Current (amperes)	Impedance (ohms)	Efficiency (per cent)	References
High-Vacuum Charger	250 Sr—Y-90	direct charging	to 350,000	10^{-9}	10^{15}	25	[89]–[91]
Dielectric Charger	50 Sr—Y-90	direct charging	to 10,000	10^{-11}	10^{13}	up to 1	[92], [93]
Contact Potential	ionizing radiation	contact potential	1 per cell	10^{-11}	10^{8}–10^{11}	0.01	[95], [96]
Semiconductor Junction	250 Sr—Y-90	electron voltaic	0.3 per cell	10^{-5}	10^{2}–10^{4}	2.5	[97], [98]
Thermojunction	150×10^{3} Po—210	thermoelectric	0.75	25×10^{-3}	—	0.2	[99], [100]
Photovoltaic	4.5×10^{3} Pm-147	photovoltaic	1	10^{-5}	—	1	[101]

with the lead-acid automotive batteries. On light drain application the pocket and sintered-plate batteries have similar characteristics. Since the sintered-plate construction is relatively new, the life characteristics of these batteries have not been completely determined.

4) *Zinc-Silver Oxide Batteries:* Zinc-silver oxide batteries [83]–[85] represent a new class of secondary batteries which have become commercially available since World War II. The theoretical possibilities of using this electrochemical system have been recognized for many years. However, it was not until H. G. André demonstrated in the early thirties that the active anode and cathode materials could be kept separated during the charging and discharging processes that a practical zinc-silver oxide secondary battery was realized. This was accomplished by using a semi-permeable membrane separator.

These batteries can furnish higher currents and give three to five times greater watt-hour capacities per unit of weight and volume than the lead-acid, nickel-iron, or nickel-cadmium storage batteries. They are particularly adapted for delivering high watt-hour capacities at discharge rates less than 30 minutes, which makes them attractive for many special military applications. However, because they are more expensive and have a shorter cycle life than the conventional storage batteries, they have not found wide commercial usage.

5) *Cadmium-Silver Oxide Batteries:* The recently announced cadmium-silver oxide battery [86] combines the high capacity features of the silver oxide cathode with the favorable cycling and low-rate discharge characteristics of the cadmium anode. Other than the replacement of the zinc sponge anode with a cadmium sponge, the construction of these batteries is similar to the zinc-silver oxide batteries.

These batteries at the present stage of development give about 2.5 times the watt-hour capacity per unit of weight and volume of comparable nickel-cadmium batteries. However, not enough data are available on cycle life, to make an over-all performance comparison of these two batteries. Compared with the zinc-silver oxide battery, they give about 40 per cent less capacity and are not suitable for high rate discharge. They are recommended for low rate and long cycle life applications.

6) *New Developments:* Several new battery systems under development are lead-silver oxide [87], cadmium-mercuric oxide [88], zinc-nickel dioxide [26], and iron-silver oxide [26]. The properties of some of these are given in Table VI. Two of these cells, lead-silver oxide and cadmium-mercuric oxide, have been designed for specialized applications.

III. CONVERSION OF NUCLEAR ENERGY TO ELECTRICAL ENERGY

The direct conversion of nuclear energy to electrical energy has recently attracted considerable attention. The immediate interest lies in the possible application of such processes to produce simple, reliable, long-life power sources.

At the present stage of development, nuclear batteries cannot be used for conventional power demands such as encountered in lighting and automotive applications, as they are not suitable for supplying more than microwatts of power. However, for uses which require long shelf life, for continued use of low current over long periods of time as in earth satellites, or for equipment in inaccessible regions, nuclear cells have merit. Another advantage of these cells is that they are temperature independent and can operate at extremes of temperature, where other conventional cells fail.

The future usefulness of the nuclear batteries depends upon the solution of several problems, such as the high cost of radioactive material, radiation shielding, and the low-energy conversion efficiency.

The various nuclear batteries are summarized briefly in the following parts and their performance characteristics in Table VIII.

A. Direct Charging

This method of conversion uses only charged radiation and involves the simple collection of charged carriers by an electrode to create a voltage. These direct charging devices consist of three principal parts; a radioactive source, an insulating medium between the electrodes, and a metal collector. This type of cell is capable of producing high voltages if enough time elapses to build up a charge of electrons. They are limited in their usefulness by low currents and high impedances, as seen by the data in Table VIII. The current and the impedance depend upon the amount of radioactive material used; however, the use of large amounts is not feasible due to the present high cost of such materials and the need for shielding.

Commercial batteries of this type are available [94] with voltage ratings from 1 to 10,000 volts and current ratings from 5×10^{-12} to 5×10^{-9} amperes.

B. Contact Potential Difference

This method utilizes both charged and uncharged radiation, and operates by using contact potential fields [95], [96] to separate charges and to produce currents. The basic principle of this cell is illustrated in Fig. 20. Here are shown two electrodes of dissimilar metals or surfaces, between which there is enclosed an atmosphere of gas, for example argon. Radiation of any type having sufficient energy to ionize the gas produces carrier pairs. These are acted upon by the field due to the contact potential difference of the metal surfaces, the positive ions flowing in one direction and the negative electrons in the opposite. This produces an electric current which may pass through an external load R and do useful work.

In this cell, which has an especially low efficiency due mainly to the small absorption coefficient of gases for radioactive radiation, the maximum output voltage is the contact potential difference.

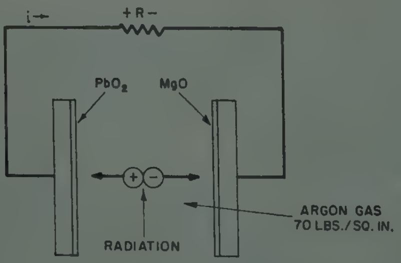


Fig. 20—Diagram of contact potential device.

C. Semiconductor Junction

When beta particles are absorbed by a semiconductor they dissipate most of their energy by ionizing the atoms of the solid. The carriers generated in this fashion are in excess of the number permitted by thermodynamic equilibrium and if they diffuse to the vicinity of a rectifying junction, they induce a voltage across the junction.

A power generating device [97], using this phenomenon (electron-voltaic effect), is shown schematically in Fig. 21. The junction consists of silicon, with p type on the left and n type on the right, with a source of ionizing radiation placed near this junction.

Because of the high multiplication accompanying the absorption of beta particles in the semiconductor, this type of device gives a higher current and lower impedance than the direct charging types. The disadvantage of this cell, which uses high energy beta particles, is its short life which results from the radiation damage of the silicon crystals.

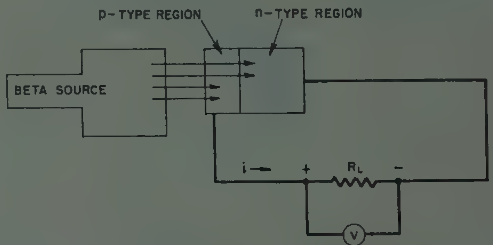


Fig. 21—Schematic diagram of semiconductor converter and circuit.

D. Thermojunction

This type of nuclear cell makes use of a thermopile which converts the heat from radioactive decay into electricity [99], [100]. The battery, developed by Birden and Jordan [99] uses 150 curies of polonium 210 as the source of nuclear radiation, and maintains a temperature difference of about 232°C (450°F) between the hot and cold junctions of 40 thermocouples. The disadvantages of this particular cell is that polonium decays with a relatively short half life of 138 days and is quite expensive.

E. Photovoltaic

The application of the photovoltaic effect to the conversion of radioactive energy to electrical energy consists of two steps, 1) converting the radioactive energy to photons by the use of scintillating media, and then 2) utilizing these photons to eject electrons from a suitably prepared surface. The electrons flow to a collecting electrode and through an external load.

A cell of this type [101], which uses a silicon photocell and a light source consisting of a mixture of promethium oxide and a phosphor, has recently been announced. The voltage of this cell remains essentially constant, while the current decays exponentially with the decay of the radioactive material. Thus, for this particular cell, the power output drops to about one-half of its initial value after two and one half years, which is the half life of promethium 147.

IV. Conversion of Solar Energy to Electrical Energy

As an outgrowth of the extensive work on solid-state materials, silicon photovoltaic converters have been developed [102]–[104] which make use of a special type of barrier layer between two semiconductors known as a p-n junction. When radiant energy strikes this junction, a potential disturbance occurs which can be utilized to deliver electric power to an external circuit.

A typical set of curves for this cell is shown in Fig. 22, in which the open-circuit voltage V_0 is plotted as a function of the sunlight intensity, and where the power output and efficiency for full sunlight (100 mw/cm²) is plotted as a function of the voltage, which varies due to a variation of load resistance.

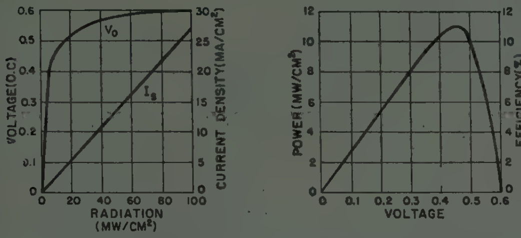


Fig. 22—Typical curves showing current-voltage and power relations of silicon solar battery.

The over-all efficiency of this device, which is 11 per cent in full sunlight, is limited by the following factors [104]: 1) some of the radiant energy is lost by reflection from the silicon surface, 2) up to 30 per cent of the hole-electron pairs may be lost by recombination, and 3) the internal resistance of the cell itself.

Another type of solar converter is the cadmium sulfide cell [105] which has an open-circuit voltage of 0.45 volt, a short-circuit current of 15 ma/cm², and an efficiency of 5 per cent. This material, which has a band gap of 2.4 ev as compared to 1.1 ev for silicon, shows an anomolous photovoltaic response in that it responds to light energies below the band gap energy at about 1.8 to 2.0 ev, depending upon impurity content.

More recently, solar cells were made using CdTe, InP, and GaAs [106]. Conversion efficiencies ranging from 2 per cent to 6.5 per cent have been achieved. Considerable improvement in these results is expected as the technology of these new semiconductors is advanced.

Selenium and silicon photovoltaic cells are commercially available. For selenium, the maximum efficiency for conversion of full sunlight is between 0.5 per cent and 1 per cent. Thus a cell of this type will produce about 0.5 mw/cm² in average sunlight and have an open-circuit voltage about 0.5 volt, and a short-circuit current about 2 ma. For silicon cells, the efficiency of conversion is about 8.8 per cent for the average production unit. However, selected units with efficiencies above 10 per cent are also available at higher cost. To be cost competitive with a Leclanché dry cell, a solar cell must last ten years, assuming it operates at an efficiency of 8 per cent [107].

The chief problems associated with solar cells is the high cost of materials, and the need for a simple, cheap storage cell having a life equal to the solar cell itself, so that the power source can continue to operate in the absence of adequate light [108].

Bibliography

[1] Latimer, W. M. *Oxidation Potentials.* New York: Prentice-Hall, Inc., 1952.
[2] Walkley, A, "The Potential and Coulombic Capacity of Some Galvanic Cell Systems," *Journal of the Electrochemical Society,* vol. 99 (August, 1952), pp. 209C–214C.
[3] Vinal, G. W. *Primary Batteries,* New York: John Wiley and Sons, Inc., 1950.
[4] Heise, G. W., and Cahoon, N. C. "Dry Cells of the Leclanché Type, 1902–1952—A Review," *Journal of the Electrochemical Society,* vol. 99, August, 1952, pp. 179C–187C.
[5] Ruben, S.; "Balanced Alkaline Dry Cells," *Transactions of the Electrochemical Society,* vol. 92 (1947), pp. 183–193.
[6] Friedman, M., and McCauley, C. E., "The Ruben Cell, A New Alkaline Primary Dry Cell Battery," *Transactions of the Electrochemical Society,* vol. 92 (1947), pp. 195–215.
[7] Booe, J. M. "The Alkaline-Mercury Oxide Cell," *Journal of the Electrochemical Society,* vol. 99 (August, 1952), pp. 197C–200C.
[8] Dalfonso, J. L., "Alkaline Dry Batteries," *Proceedings of the Tenth Annual Battery Research and Development Conference,* Power Sources Division, Signal Corps Engineering Laboratories, Fort Monmouth, N.J., pp. 11–14, 1956.
[9] Herbert, W. C., "The Alkaline Manganese Dioxide Dry Cell," *Journal of the Electrochemical Society,* (August, 1952), pp. 190C–191C.
[10] Kirk, R. C., and Fry, A. B., "Magnesium Dry Cells," *Journal of the Electrochemical Society,* vol. 94 (1948), pp. 277–289.
[11] Fry, A. B., Kirk, R. C., and George, P. F. (to Dow Chemical Co.) U.S. Pat. 2,547,907, April 3, 1951; U.S. Pat. 2,547,908, April 3, 1951; U.S. Pat. 2,547,909, April 3, 1951.
[12] Kirk, R. C., George, P. F., and Fry, A. B. "High Capacity Magnesium Dry Cells," *Journal of the Electrochemical Society,* vol. 99 (August, 1952), pp. 323–327.
[13] Glicksman, R. and Morehouse, C. K. "Investigations of the Electrochemical Characteristics of Organic Compounds. I. Aromatic Nitro Compounds," *Journal of the Electrochemical Society,* vol. 105 (June, 1958), pp. 299–305.
[14] Morehouse, C. K., and Glicksman, R. "Dry Cells Containing Various Aromatic Nitro Compounds as Cathode Materials," *Journal of the Electrochemical Society,* vol. 105 (June, 1958), pp. 306–311.
[15] Glicksman, R., and Morehouse, C. K. "Investigation of the Electrochemical Characteristics of Organic Compounds. II. Aromatic Nitroso Compounds," the *Journal of the Electrochemical Society,* submitted for publication.
[16] Morehouse, C. K., and Glicksman, R. "Dry Cells Containing Various Aromatic C-Nitroso Compounds as Cathode Materials," *Journal of the Electrochemical Society,* submitted for publication.
[17] —, —. "Magnesium-Bismuth Oxide Dry Cells," *Journal of the Electrochemical Society,* submitted for publication; U.S. Pat. 2,809,225, October 8, 1957 (to Radio Corporation of America).
[18] Schumacher, E. A., and Heise, G. W. "The Alkaline Cell with Copper Oxide or Air Depolarization (1902–1952)," *Journal of the Electrochemical Society,* vol. 99 (August, 1952), pp. 191C–196C.
[19] Schumacher, E. A. "Air Depolarized Batteries," See [8], pp. 14–19.
[20] Boswell, T. L. (to Elgin National Watch Company). U.S. Patent 2,683,184, July 6, 1954.
[21] Stokes, J. J., Jr. "The Aluminum Dry Cell," unpublished paper presented at the Electrochemical Society Meeting, Pittsburgh, Pa., October, 1955.
[22] Leclanché, G. *Les Mondes,* vol. 16 (1868), pp. 532–535. Also *Comptes rendus,* vol. 83 (1876), p. 54.
[23] Gassner, C. German Patent 37,758, April 8, 1886; U.S. Patent 373,064, November 15, 1887.
[24] Tomassi, D. *Traite des Piles Electriques.* Paris: Georges Corre, pp. 267–271, 1889.
[25] Vinal. See [3], p. 45.
[26] Hamer, W. J. "Modern Batteries," IRE TRANSACTIONS ON COMPONENT PARTS, vol. CP-4 (September, 1957), pp. 86–96.
[27] Birdsall, C. G. "Leclanché Batteries." See [8], pp. 1–3.
[28] Anthony, H. R. C. U.S. Patent 2,198,423, April 23, 1940.
[29] Morehouse, C. K., and Welsh, J. Y. (to Olin-Matheson Chemical Corporation). U.S. Patent 2,748, 183, May 29, 1956.
[30] Adams, P. H. "Developments in Dry Batteries and Associated Electronic Equipment," "PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, vol. 12 (August, 1951), pp. 167–178.
[31] Huntley, A. K. "A Radio 'B' Dry Battery of Flat Type Construction," *Transactions of the Electrochemical Society,* vol. 68 (1935), pp. 219–230.
Reid, C. J., and Morrill, M. T. U.S. Patent 690,772, January 7, 1902.

[32] French, H. F., "Improvements in B-Battery Portability," PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, vol. 29 (June, 1941), pp. 299–303. U.S. Patent 2,272,969.

[33] Franz, A. O., Martinez, J. M., and Koppelman, M.D. (to Olin Industries). U.S. Patent. 2,416,576, February 25, 1947.

[34] Vinal, See [3], pp. 127–159.

[35] Otto, E., Morehouse, C. K., and Vinal, G. W. "Low Temperature Dry Cells," *Transactions of the Electrochemical Society*, vol. 90 (1946), pp. 419–432.

[36] Kameyama, M. and Naka, A. "Investigation of Low Temperature Dry Cells," *Journal of the Society of the Chemical Industry, Japan*, vol. 39 (1936), pp. 871.

[37] Wilke, M. E. "Dry Cell Designed to Operate at −40°C Containing Lithium Chloride in the Electrolyte," *Transactions of the Electrochemical Society*, vol. 90 (1946), pp. 433–440.

[38] *American Standard Specification for Dry Cells and Batteries.* National Bureau of Standards Circular 559, 1955.

[39] U.S. Military Specifications, Batteries, Dry, MIL-B-18R, Amendment No. 2, September 20, 1956.

[40] Clarke, C. L., U.S. Patent, 298,175, May 6, 1884.

[41] Aron, H., German Patent 38,220, December 13, 1886.

[42] Edison, T. A., U.S. Patent, 704,303, July 8, 1902.

[43] Morrison, W. U.S. Patent 916,575, March 30, 1909; 975,885, 975,980, and 976,092, November 15, 1910. German Patent 273, 143, April 24, 1914.

[44] Bronsted, J. N., German Patent 296,397, February 7, 1917, U.S. Patent 1,219,074, March 13, 1917.

[45] Morehouse, C. K. "Magnesium Primary Batteries," *Journal of the Electrochemical Society*, vol. 99, (August, 1952), pp. 187C–189C.

[46] Hovendon, J. M. "Magnesium Batteries." See [8], pp. 8–10.

[47a] Lehovic, K. "Solid Electrolyte Batteries." See [8], pp. 50–53.

[47b] Shapero, S. J. "Solid Electrolyte Batteries," *Proceedings of the Eleventh Annual Research and Development Conference*, Power Sources Branch, U.S. Army Signal Engineering Laboratories, Fort Monmouth, N.J., pp. 3–5, 1957.

[48] Wood, R. E. "Punched-Cell Batteries with Polyethylene Glycol Electrolytes," *Journal of the Electrochemical Society*, vol. 103 (1956), pp. 417–420.

[49] Morse, E. M. "Water-Activated Batteries." See [8], Also, See [47b], pp. 69–72.

[50] *Water-Activated Batteries.* General Electric Technical Brochure, No. GEA 6238A, 12/55 (9 M).

[51] Blake, I. C. "Silver Chloride-Magnesium Reserve Battery," *Journal of the Electrochemical Society*, vol. 99 (August, 1952), pp. 202C–203C.

[52] Pucher, L. E. "The Cuprous Chloride-Magnesium Reserve Battery," *Journal of the Electrochemical Society*, vol. 99 (August, 1952), pp. 203C–204C.

[53] Morehouse, C. K., and Glicksman, R. "N-Halogen Organic Compounds as Cathode Materials for Primary Batteries," *Journal of the Electrochemical Society*, vol. 104 (1957), pp. 467–473.

Lozier, G. S., Cutler, L. H., and Morehouse, C. K. "Organic N-Halogen-Magnesium Reserve Batteries," Extended Battery Abstracts of the Electrochemical Society Meeting, Buffalo, N.Y., pp. 52–53, October, 1957.

Lozier, G. S., "Organic Depolarizers," See [47b], pp. 8–10.

[54] Howard, P. L. "The Silver Peroxide-Zinc Alkaline Cell," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 200C–201C.

[55] Wilburn, N. T. "Zinc-Silver Oxide Batteries," See [8], pp. 20–22.

——. "Development and Reliability Investigations of Zinc-Silver Oxide Missile Batteries," See [47b(, pp. 58–61.

[56] Schlotter, W. J. "The Lead Dioxide-Zinc Reserve Type Cell," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 205C–206C.

[57] Schrodt, J. P., Otting, W. J., Schoegler, J. G., and Craig, D. N. "A Lead Dioxide Cell Containing Various Electrolytes," *Transactions of the Electrochemical Society*, vol. 90 (1946), pp. 405–417.

[58] Pucher, L. E. "The Lead Dioxide-Cadmium Reserve Type Cells," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 204C–205C.

[59] Kilmer, S. B., Lawson, H. E., and Randolph, C. L. "Chlorine-Depolarized Battery," See [8], pp. 29–32.

Langworthy, E. M., Randolph, C. L., and Lawson, H. E. "Chlorine-Depolarized Battery." See [47b], pp. 67–69.

[60] Howard, P. L. "The Chlorine-Zinc Primary Cell," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 206C–207C.

[61] Gleason, H. S., and Freund, J. M. "Amonia Vapor Activated Batteries," Extended Battery Abstracts of the Electrochemical Society Meeting, Buffalo, N.Y., pp. 31–32, October, 1957.

Gleason, H. S., and Minnick, L. J., "Amonia Vapor Activated Batteries." See [47b], pp. 13–16.

[62] Evans, G. E. "Boron Trifluoride Batteries." See [47b], pp. 11–13.

[63] McKee, E. "Thermal Cells." See [8], pp. 26–28, 1956.

[64] Goodrich, R. B., and Evans, R. C. "Thermal Batteries," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 207C–208C.

[65] Gorin, E., and Recht, H. L. "Fuel Cells. See [8], pp. 53–56, 1956.

[66] Adams, A. M. "Electrochemical Cells as Energy Converters," AIEE Conference Paper, No. C. P. 56–266, pp. 1–16, January, 1956.

[67] Vinal. See [3] pp. 160–213.

[68] Vinal. See [3], pp. 321–323.

[69] Vinal, G. W. *Storage Batteries*. New York: John Wiley and Sons, Inc., 4th ed., 1955.

[70] Willihnganz, E. "Batteries (In Part)," in *Encyclopaedia Britannica*, vol. 3, pp. 217E–218, 1956.

[71] Lord, E. L., and Anderson, F. C. *Batteries—Standard Handbook for Electrical Engineers.* Edited by A. E. Knowlton, 9th ed. New York: McGraw-Hill Book Company, Inc., pp. 1891–1940, 1957.

[72] Willihnganz, E., "The Lead-Acid Automotive Battery," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 234C–236C.

[73] Riggs, N. C. "Lead-Acid Motive Power and Carlighting Batteries," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 236C–238C.

[74] Thomas, U. B. "Lead Acid Stationary Batteries," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 238C–241C.

[75] Rose, C. C., and Zachline, A. C. "Low Discharge Cells," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 243C–244C.

[76] Jensen, H. E. "Calcium-Lead Grid Batteries," See [47b], pp. 73–77.

[77] Endress, C. N., and Rose, C. C. "Plastic Container-Electrolyte Retaining Lead-Acid Storage Batteries," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 241C–243C.

[78] Anderson, F. C. "The Edison Nickel-Iron-Alkaline Cell," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 244C–248C.

[79] Bergstrom, S. "Nickel-Cadmium Batteries," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 248C–250C.

[80] Ellis, G. B., Mandel, H., and Linden, D. "Sintered Plate Nickel-Cadmium Batteries," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 250C–252C.

[81] Fleischer, A. "Vented Ni-Cd Batteries," See [47b], pp. 83–86.

[82] Belove, L, and Schulman, I. M. "Sealed Sintered Plate Ni–Cd Batteries," See [47b], pp. 41–44.

[83] Eidensohn, S. "The Zinc-Silver Peroxide Alkaline Storage Battery," *Journal of the Electrochemical Society*, vol. 99 (1952), pp. 252C–254C.

[84] Howard, P. L. *Zinc-Silver Oxide Batteries*, Technical Bulletin, Yardney Electric Corporation.

[85] ——. *The Silver-Zinc Rechargeable Battery*. Technical Bulletin, Yardney Electric Corporation.

——. "Zinc-Silver Oxide Batteries," See [8], pp. 4144.

[86] ——. *The Silver Oxide-Cadmium Alkaline Secondary Battery.* Technical Bulletin, Yardney Electric Corporation.

——. "Cadmium-Silver Oxide Batteries." See [47b], pp. 78–80.

[87] Goldberg, M. B., and Reed, H. B., Jr. (to U.S. Government). U.S. Patent 2,697,736, December 21, 1954.

[88] ——, ——. (to U.S. Government). U.S. Patent 2,697,737, December 21, 1954.

——, ——. "A New Rechargeable Dry Cell," Extended Abstracts of the Electrochemical Society Meeting, Buffalo, N.Y., pp. 31–35, 1957.

[89] Linder, E. G. "Nuclear Electrostatic Generator," *Physical Review*, vol. 71 (1947), pp. 129–130.

[90] Linder, E. G., and Christian, S. M. "The Use of Radioactive Material for the Gerneration of High Voltages," *Physical Review*, vol. 83 (1951), p. 233.

[91] ——, ——. "The Use of Radioactive Material for the Generation of High Voltage," *Journal of Applied Physics*, vol. 23 (1952), pp. 1213–1216.

[92] Linder, E. G., and Rappaport, P. "Radioactive Charging Through a Dielectric Medium," *Physical Review*, vol 91 (1953) pp. 202.

[93] Rappaport, P., and Linder, E. G. "Radioactive Charging Effects with a Dielectric Medium," *Journal of Applied Physics*, vol. 24 (1953), p. 1110.

[94] *Nuclear Batteries.* Patterson-Moos Division, Universal Winding Company, Technical Brochure.

[95] Kramer, J. B. "A New Electronic Battery," *The Electrician*, vol. 93 (1924), p. 479.

[96] Ohmart, P. E. "A Method of Producing and Electric Current from Radioactivity," *Journal of Applied Physics*, vol. 22 (1951), pp. 1504–1505.
[97] Rappaport, P. "The Electron-Voltaic Effect in *P-N* Junctions Induced by Beta-Particle Bombardment," *Physical Review*, vol. 93 (1954), pp. 246–247.
[98] Rappaport, P, Loferski, J. J., and Linder, E. G. "The Electron-Voltaic Effect in Germanium and Silicon *P-N* Junctions," *RCA Review*, vol. 17 (1956), pp. 100–128.
[99] "Radioactive Heat to Electricity," *Chemical Engineering News*, vol. 32 (1954), p. 4183.
[100] Blanke, B. C., "Thermoelectric-Type Nuclear Batteries," See [47b], pp. 109–110.
[101] Miller, R. C. "The Elgin-Kidde Nuclear Battery," See [47b], pp. 102–105.
[102] Chapin, D. M., Fuller, C. S., and Pearson, G. L. "A New Silicon *P-N* Junction Photocell for Converting Solar Radiation into Electrical Power," *Journal of Applied Physics*, vol. 25 (1954), pp. 676–677.
[103] ——, ——, ——. "The Bell Solar Battery," Bell *Laboratories Record*, vol. 33 (1955), pp. 241–246.
[104] Pearson, G. L. "Conversion of Solar to Electrical Energy," *American Journal of Physics*, vol. 25 (1957), pp. 591–598.
[105] Reynolds, D. C., Leies, G., Antes, L. L., and Marburger, R. E., "Photovoltaic Effect in Cadmium Sulfide," *Physical Review*, vol. 96 (1954), pp. 533–534.
[106] Rappaport, P., and Loferski, J. J. "New Solar Converter Materials." See [47b], pp. 96–99.
[107] Linder, "Solar Batteries." See [8], pp. 59–62.
[108] Lunz, "Sealed Cells with Solar Converters." [47b], pp. 89–92.

The Resnatron as a 200-MC Power Amplifier[*]

E. B. TUCKER[†], H. J. SCHULTE[‡], E. A. DAY[§], AND E. E. LAMPI[||]

Summary—**Tetrode amplifiers (resnatrons) used to power the Minnesota Linear Proton Accelerator are described. These demountable tubes are continuously pumped, grid pulsed 202-mc amplifiers capable of a peak power output of 3.5 megw during 300-μsec pulses with two per cent duty cycle. A transconductance of 0.12 mho and power gains of 10 have been observed. Reliability has been surprisingly good. Life limitation is due to crystallization of the pure tungsten filaments. The average time between pull-downs because of filament trouble varies from 700 to 1140 hours of operation. The lower life corresponds to higher power service conditions.**

INTRODUCTION

THE RESNATRON originated about 1938 when Sloan and Marshall developed an oscillator which depended upon the relationship between transit time and frequency to provide the proper feedback phase.[1,2] During World War II, resnatrons were developed for jamming purposes as noise-modulated cw oscillators.[3] Subsequent to the war years, Collins Radio Company of Cedar Rapids, Iowa, carried on some resnatron work both as oscillators and as amplifiers. In general, the objective of all these tubes was the development of high cw power, and power outputs of the order of 60 kw were obtained.[4,5] It should be noted that as an amplifier it is not necessary and is, in fact, undesirable for the transit time to play the same role that is played in the original oscillator. The name resnatron when it is used today appears to denote a tetrode with a particular tube construction in which the cavities and tuners are all contained in the vacuum envelope, rather than a particular type of tube. The resnatron herein described is a tetrode in which the screen operates at the same dc potential as the anode.

When the Minnesota Linear Proton Accelerator was first contemplated, there was an obvious need for an amplifier capable of very high peak powers; in this case 200 mc appeared to be an optimum frequency. It was estimated that in order for the fields in the large accelerator cavities to be built up within a reasonable length of time, it would be ideal to use a shaped rf pulse so that the power available during the first 50 μsec of the pulse would be 8 megw and the power for the remainder of the 300-μsec pulse would be such that the average power during the pulse would be 4 megw. The high rf drive at the first of the pulse would serve to build the rf level in the tank up to the 4-megw operating level faster than the usual rectangular pulse. There was not at that time (1949–1950), nor is there today, a commercially available tube capable of providing such power. The resnatron-type tube, with its reputation for high average power, seemed the most logical choice, with various ring circuit arrangements being the only alternatives. In 1950, the Collins Radio Company was given a contract to develop and build five tubes with specifications similar in outline to those given above. The general design was made by W. W. Salisbury. In April, 1953, the contract was canceled by mutual agreement and the final development and testing of the tubes were carried out in Minneapolis by the accelerator staff of the University of Minnesota.

---

[*] Original manuscript received by the IRE, November 25, 1957; revised manuscript received, March 10, 1958. This work was supported by the Atomic Energy Commission.

[†] General Electric Res. Lab., Schenectady, N. Y., formerly with Univ. of Minn., Minneapolis, Minn.

[‡] Bell Telephone Labs., Murray Hill, N. J., formerly with Univ. of Minn., Minneapolis, Minn.

[§] Midwestern Universities Res. Assn., Madison, Wis., formerly with Univ. of Minn., Minneapolis, Minn.

[||] Bell Telephone Labs., Allentown, Pa., formerly with Univ. of Minn., Minneapolis, Minn.

[1] D. H. Sloan and L. C. Marshall, *Phys. Rev.*, vol. 58; 1940.

[2] D. H. Sloan, U. S. Patents Nos. 2,404,541; 2,404,542; 2,405,762; and 2,405,763.

[3] W. G. Dow and H. W. Welch, "Very High Frequency Techniques," McGraw-Hill Book Co., Inc., New York, N. Y., vol. 1, ch. 19; 1947.

[4] W. W. Salisbury, "The resnatron," *Electronics*, vol. 19, p. 92; February, 1946.

[5] D. B. Harris, "New UHF resnatron designs and applications," *Electronics*, vol. 24, pp. 86–89; October, 1951.

It should be emphasized that a minimal number of changes was made at Minnesota in both mechanical and rf design. Therefore, there are, in the final tube, many design details for which Collins Engineers should have full credit.

General Description

The Minnesota resnatrons are massive structures of copper and iron. The top of the tube stands some fifteen feet above the floor on which the iron base plate is supported by four iron legs. Because of the large area of rubber gasketing used in the vacuum joints, the tubes are continuously pumped by means of a 1400 C.F.M. oil-diffusion pump operated with a freon refrigerated baffle (which cuts the pumping speed by a factor of two). Exclusive of the vacuum pump, the tube weighs about 2½ tons. In addition to the usual elements necessary for a tetrode, the vacuum enclosure contains all of the rf cavities, tuners, water-cooling coils, and a 100-kv dc isolation choke. The tube is readily dismantled for filament replacement or other repairs.

The resnatron is a coaxially arranged beam tetrode with screen and anode operated at the same dc potential. Due to the far-from-ideal vacuum conditions, a pure tungsten filament is used. The cathode consists of 36 strands of tungsten with approximately five inches of emitting length per strand. Thus the tube in reality consists of 36-unit tetrodes operating in parallel. The 60-cycle filament power of 7000 amperes at 6 volts is provided by a step-down transformer with a single-turn secondary of sheet copper with a cross section of 12 square inches. One side of the secondary is operated at ground potential.

All elements of the tube, with the exception of the filament itself, are water cooled. This necessitates the provision of three purified-water supplies at potentials different from ground. The tubes are operated class C with grounded grid circuits. The grid is driven by an rf pulse of the appropriate shape. The only unusual feature of this operation is that here we have a continuously pumped tube standing off voltages in the range of 70 kv both during and between pulses. Of course the 300-μsec pulse is long enough so that, with the exception of power dissipation, the operation is essentially cw.

The rf power-distribution system of the accelerator (see Fig. 1) is, for the high-power portion, aluminum waveguide with dimensions 40 by 12 inches. There is need for transition from waveguide to coaxial line at both input and output of the resnatrons, since the tubes are coaxial by design. Three of the four tubes used in the system drive individual cavities of the linear accelerator while the fourth acts as the driver for the other three. The input to the latter tube is provided by a frequency multiplier and amplifier chain which produces a pulse power of 200 kw at a frequency of 202.55 mc.

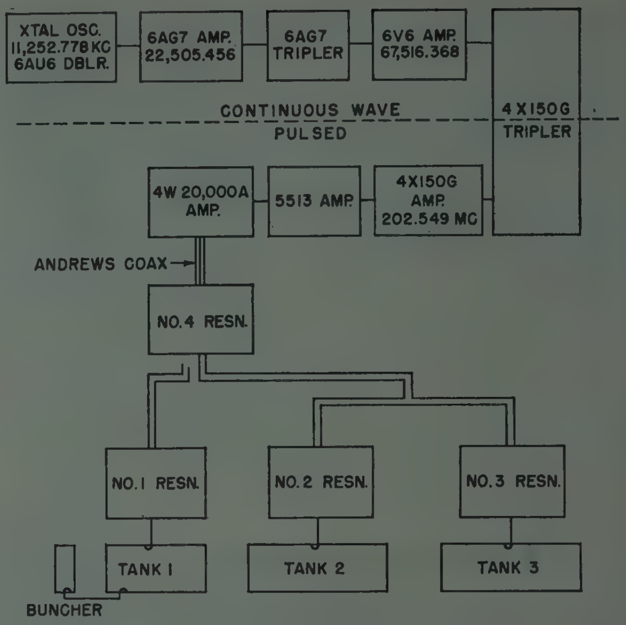


Fig. 1—Block diagram of the radio frequency system of the Minnesota Linear Accelerator. The distribution system between resnatrons and from resnatrons to tanks is aluminum waveguide.

Electrode Configuration and Characteristics

Each individual sector of the tube has the typical beam tetrode electrode arrangement. Cross-section drawings of these 10° sectors are given in Fig. 2, while the vertical section for the final design of Fig. 2(b) is given in Fig. 3.

The indentations in the anode are secondary electron traps which are often used in tubes operating with screen and anode at the same dc potential. The operation of these secondary traps depends on transit time. The fields of the output cavity are concentrated between the screen bars and the anode fins. Electrons passing through the gap in such phase as to excite the fields will, therefore, lose most of their energy in this strong field region, and then will proceed toward the anode wall. Even though these primary electrons strike the anode wall with reduced velocity, they will, in general, have enough energy to produce secondaries. The phase of the fields in the output cavity (assuming it unchanged) is such as to accelerate these secondaries toward the grid, but they will travel relatively slowly and be accelerated by weak fields until the anode fin tips are reached. The traps are made deep enough so that the phase of the fields in the anode cavity reverses before the secondaries reach the strong field region. Secondaries are thus prevented from returning to the screen and loading the output cavity in this undesirable fashion. Proper behavior of these traps requires that the electron beam be narrow enough so that none of the electrons strikes the fin tips, where transit time cannot provide the suppression required. The space charge

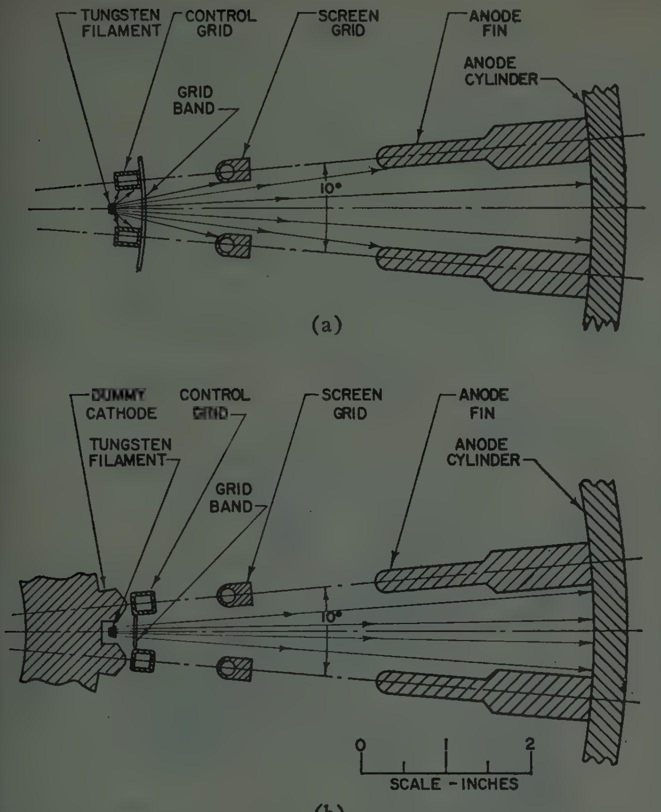


Fig. 2—Cross section of two resnatron designs. The arrows indicate possible electron trajectories for positive grid voltage. (a) Old model. (b) New model.

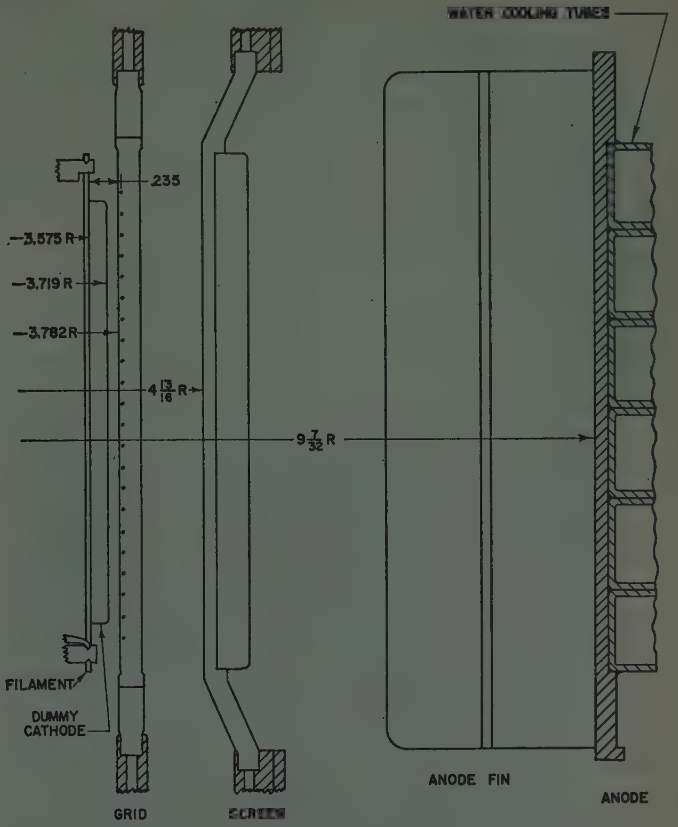


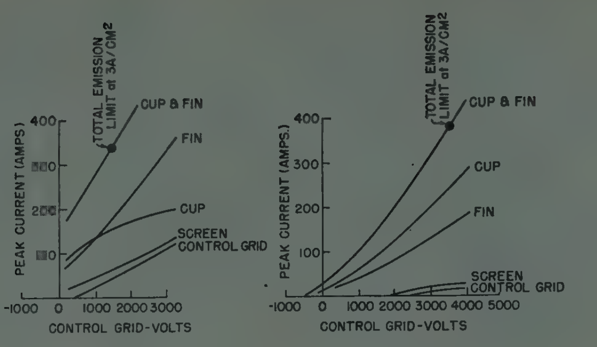
Fig. 3—Vertical section of Pierce gun design. Dummy cathode is the focussing element at ground potential. The anode water cooling tubes are soft soldered in place.

forces tend to help suppress the secondaries as well.

The shaping of the electrodes is in general such as to enhance the beam formation. The banding in the position shown in Fig. 2(a) is, however, an anomaly. Tubes without this banding derive their focussing properties from the screen-field penetration between the grid bars. Such tubes suffer from screen cathode feedback through the grid bars to the extent that a triode oscillation is set up with the screen acting as the anode. This oscillation appears to be the same mode for which the original resnatrons were designed; *i.e.*, there is a half-cycle transit from the cathode to the screen, and the feedback (because of the screen-cathode capacity) produces the correct feedback phasing. This type of oscillation should be voltage sensitive, but the oscillation was so violent that the tubes could not be pushed through the region of instability. In order to suppress the oscillations, the banding was added to the grid. However, the presence of the banding means that the beam begins to blow up as soon as the grid goes positive with respect to the cathode. Thus, one expects that such an electrode configuration would show the above mentioned anode cavity loading due to electrons striking the anode fins, and secondaries being accelerated back to the screen. Such was indeed the case.

Electrolytic tank measurements were made to test the suitability of the proposed geometries in regard to cut-off mu and the beam properties in the absence of space charge. For the geometry of Fig. 2(a), cut-off mu was 50, the mutual conductance turned out to be 0.193 mho, and of course the potential plots were such as to indicate beam blow up. In the case of the rf measurements this trouble manifests itself in a limiting of the power output at a plate current which corresponded to the grid just being driven to cathode potential. An increase of the drive power increased the plate current, but failed to increase the power output. In the actual resnatron there is no method of measuring the screen current separately from the plate current, but there is good indirect evidence that the screen current increases as the grid reaches ground potential. Incorrect loading of the plate cavity can cause a similar effect, but changes in the output coupling did not improve the situation, and the beam blow-up hypothesis is confirmed by other tests in which the screen current could be monitored.

The output power limit for the configuration of Fig. 2(a) is too low to provide sufficient power for the accelerator at reasonable plate voltages. The final configuration adopted to remedy this situation was that of Fig. 2(b), consisting of a Pierce gun in which a four-thirds power dependence of the voltage on radial distance from the cathode (as required for rectilinear flow) was approximately achieved in the grid-cathode vicinity. The actual geometry is modified somewhat from the ideal Pierce configuration to satisfy the requirements of



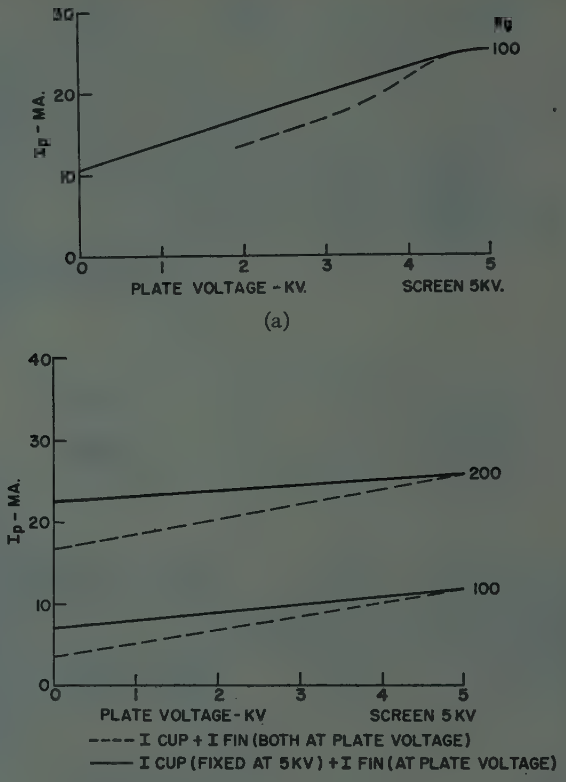
(a) (b)

Fig. 4—Triode transfer characteristics measured under dc conditions in full scale model. Voltages and currents have been scaled to values characteristic of full resnatron at 75-kv anode potential. (a) Old model. (b) New model.

reproducibility and assembly clearance. Because of mechanical difficulties, the grid-cathode spacing of the new design is greater than in the old, and thus the mutual conductance and gain are expected to be down.

In order to check the behavior of the various configurations under consideration a full-scale model of a 30° sector of the resnatron was constructed. Only the middle section of the three units was fitted with a cathode, the other sectors serving to provide the proper boundary conditions for the single beam. Since only dc tests were contemplated, the test section was only long enough to include the actual lengths of the tube elements. The model was built so that the currents to the screen, anode fins, and anode cylinder were separately monitored as contrasted to the case in the actual resnatron where the three currents are all measured as plate current.

The main objective of the model tests was to check beam characteristics. Fig. 4 gives the triode transfer characteristics for the two designs with screen and anode operated at the same potential. Under this condition, it can be seen that the screen and control grid currents are both low for the final design, whereas the old design shows a marked increase in screen and control grid currents as the grid goes positive. It should also be noted that the current to the anode cylinder drops off in the old design while in the new one this same current increases steadily. The real test of the electrode configuration is that mode of operation where the anode potential is depressed below that of the screen. This corresponds to that part of the rf cycle when electrons will deliver power to the output cavity and also when secondaries will be accelerated back to the screen. If secondaries do not return to the screen under dc conditions with the anode depressed, there is no reason to believe that they will during rf operation. Thus the screen current measured under such dc conditions is the maximum possible, and will in practice be reduced by the effectiveness of the transit-time suppression. Fig. 5 shows the useful currents measured for the two electrode configurations in the dc tests.



(a)

(b)

Fig. 5—Comparison of useful currents in two resnatron designs. Dotted lines represent current collected with anode fin and cylinder at anode potential. The solid lines show current collected with cylinder and screen both at 5 kv, and fins at potential shown as anode potential. Note that new design gives much larger fraction of useful current. (a) Old model. (b) New model.

The tube constants from the above curves are cut-off mu of 76 and a mutual conductance of 0.12 mho. The lower mutual conductance results in lower gain, but the grid can now be driven positive and the net result is that a higher power output is available. Figs. 6 and 7 give triode characteristics and estimated tetrode characteristics for the two designs. Only the Pierce gun design will be considered during the remainder of this paper.

CATHODE

One of the greatest problems in a continuously pumped tube is that of the cathode. Because of the relatively poor vacuum attained, the filaments presently in use are of pure tungsten.[6] The details of the tensioning device which is necessitated by the thermal expansion of the five-inch length of the tungsten filament are given in Fig. 8. Fig. 9 shows the assembled cathode with a heat shield covering the tensioning springs. This flexibility is provided at the lower end of the filament; the upper end is held by a fixed support. In order to provide the emission of 3 amperes per square cm required for the higher power tubes, the filament temperature must be in the vicinity of 2700°K. The water-cooled focussing electrode which partially surrounds

---

[6] The filaments and pantograph blocks were manufactured by RCA.

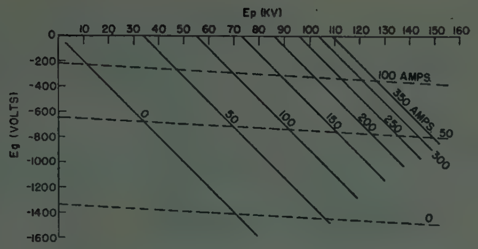


Fig. 6—Constant current characteristics for old design. Solid lines: triode characteristics, dotted lines: tetrode characteristics assuming screen 70,000 volts, gm = 0.193, cathode anode mu 2000.

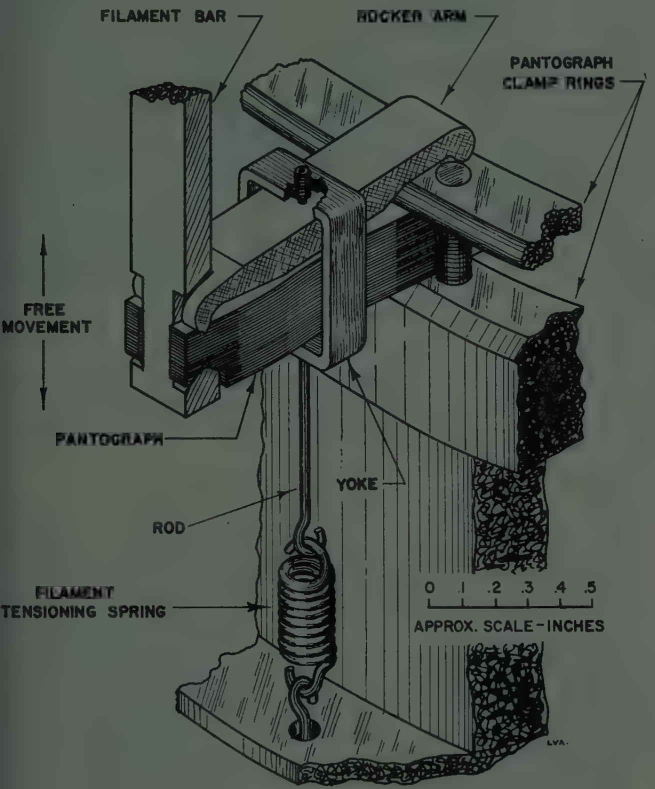


Fig. 8—Filament tensioning system. Pantograph leaves are of chrome copper, rocker arm and springs of high temperature tool steel. The temperature is around 400°C in this vicinity.

the cathode in the new design, increases the radiation oss from the filaments and hence raises the filament power required.

The temperature is kept constant over the whole length of the filament emitting area by "necking down" near the end of the filament. Trial and error tests of various lengths and neck sizes produced the final design in which the temperature variation along the active length of the filament was less than 50°K. The only connection between the filament and the copper pantograph block is a pressure contact. It appears that this behaves as a self-seating device since, if the contact s bad, the junction heats and the filament beds itself better in the copper until a good contact is made and heating stops. The centering of the filament between the supports is important and must be carefully checked during assembly. It is obvious that the proper balance between radiation and conduction will be achieved only for a good contact.

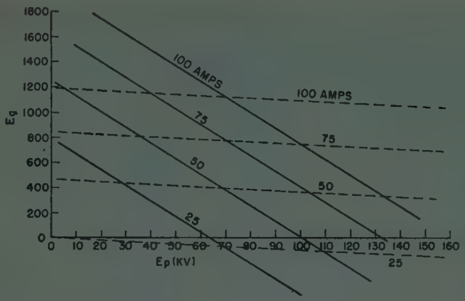


Fig. 7—Constant current characteristics of Pierce gun design resnatron. Solid lines: triode characteristics, dotted lines: estimated tetrode characteristics using 70,000 volts on screen, cathode anode mu of 2000.

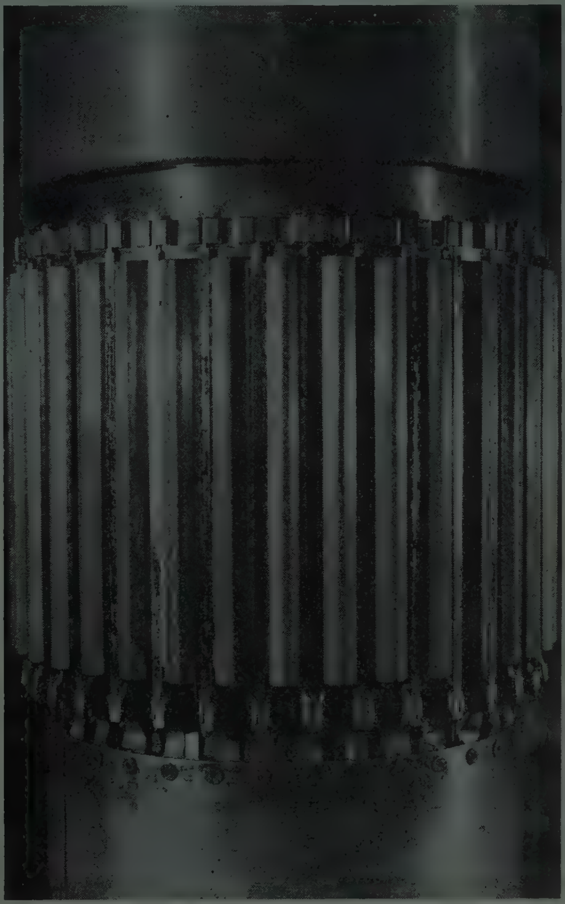


Fig. 9—Assembled cathode showing tungsten filaments in place with the fixed support at top and the pantographs below. Note that two of the pantograph leaves are used to provide rf contact from the lower end of the filament to the heat shield around the tensioning springs.

In most applications, the life of a tungsten filament is limited by weakening due to evaporation. This does not seem to be the case in this tube; instead, life is limited by filament breakage due to crystal growth and subsequent slipping along crystal planes. The majority of filaments that have failed show no measurable evaporation, but the surface shows distinct signs of crystal formation. It appears that at the operating ten-

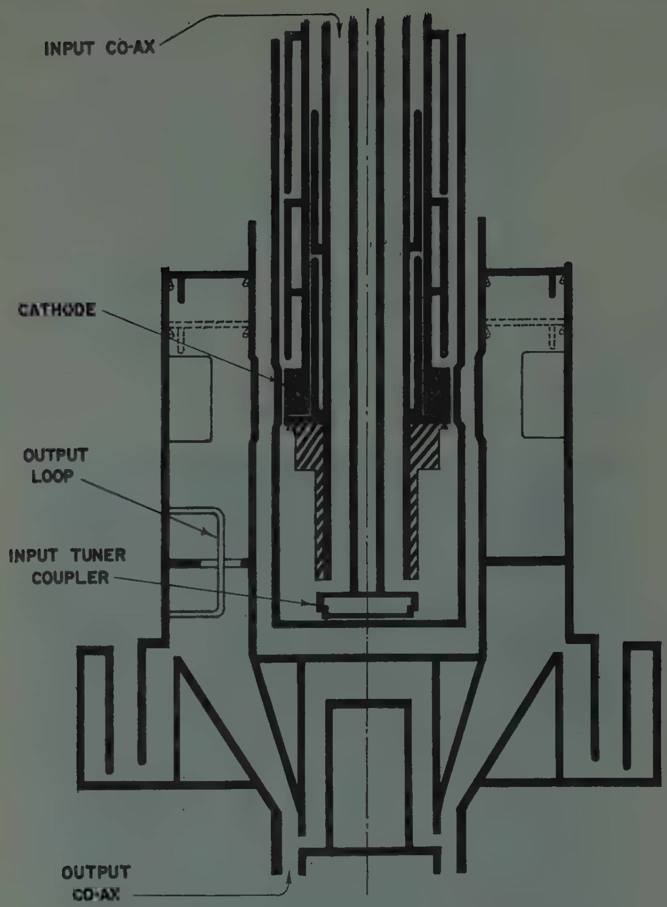

INPUT CO-AX
CATHODE
OUTPUT LOOP
INPUT TUNER COUPLER
OUTPUT CO-AX

Fig. 10—Circuits for resnatron. This is all enclosed in the vacuum system.

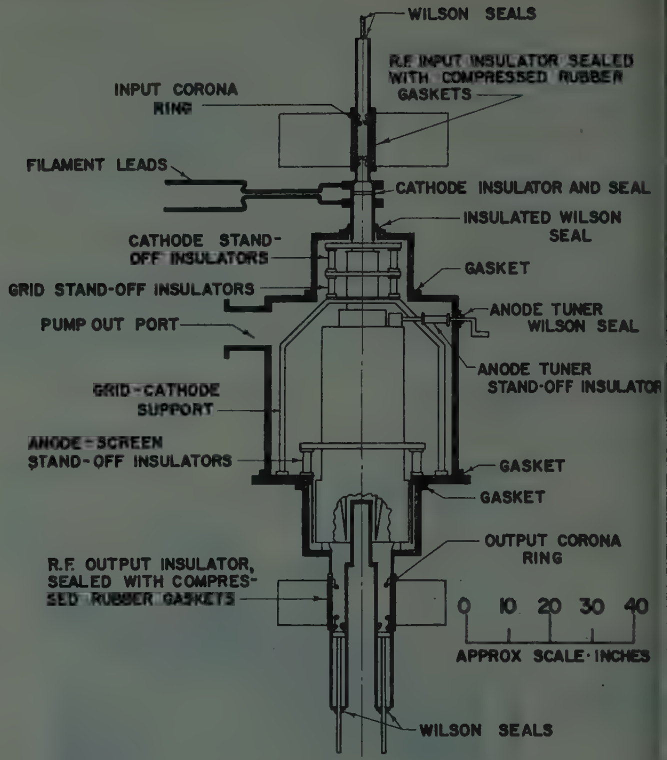

WILSON SEALS
R.F. INPUT INSULATOR SEALED WITH COMPRESSED RUBBER GASKETS
INPUT CORONA RING
FILAMENT LEADS
CATHODE INSULATOR AND SEAL
INSULATED WILSON SEAL
CATHODE STAND-OFF INSULATORS
GASKET
GRID STAND-OFF INSULATORS
PUMP OUT PORT
ANODE TUNER WILSON SEAL
ANODE TUNER STAND-OFF INSULATOR
GRID-CATHODE SUPPORT
ANODE-SCREEN STAND-OFF INSULATORS
GASKET
GASKET
OUTPUT CORONA RING
R.F. OUTPUT INSULATOR, SEALED WITH COMPRESSED RUBBER GASKETS
0 10 20 30 40
APPROX SCALE·INCHES
WILSON SEALS

Fig. 11—Mechanical layout. The legs which support the base plate are not shown.

sion and temperature, the filaments part at a crystal boundary long before evaporation has any effect. The life span, however, varies greatly. Certain of the tungsten filaments have very respectable lives of over 1000 hours; others last only a few hours. So far, no method has been found of determining, before use, which filaments will fail early. The reason was thought first to be connected with the heat and rolling treatment used to shape and work the tungsten during manufacture. Recent work, however, seems to indicate that the flexibility of the pantographs may be the unknown variable. In spite of the fact that all filaments have the same nominal treatment and look identical at the time of assembly, their behaviors vary considerably.

The filament voltage is controlled by a motorized gang of transtats which provide continuous variation from zero to full voltage. It is absolutely essential that the voltage be run up slowly enough to allow the filaments to heat gradually.

Tests are being carried out to determine whether some of the lower temperature cathodes (matrix, thoriated tungsten, etc.) will be satisfactory. So far, the rate of poisoning has been such that it precludes the use of any of these low-temperature cathodes in the existing vacuum system.

CIRCUITRY

A description of the resnatron cannot be complet without some discussion of the circuitry enclosed i the vacuum shell. The high-power rf distribution syste for the accelerator is 40 by 12 inches aluminum waveguide. Since the resnatron structure is coaxial, a waveguide-coaxial transition section is necessary at both input (top) and output (bottom). Fig. 10, which illustrate the rf circuits, does not show these transitions. Bu Fig. 11 does include them, since the vacuum seal i made at this junction. For tuning purposes, stub tuner are used on both coax and waveguide, the former bein in vacuum and the latter in air.

Power from the input transition section flows dow the input coax line to the combined coupler tuner an thence into the cathode grid cavity. The coupling t the 3/4 λ cavity is capacitive, and the filaments ar situated 1/4 λ from the upper end which is effectivel shorted by the double rf chokes. A second set of r chokes prevents loss of power between the coaxia filament leads.

The grid screen cavity should provide a low impedance at the beam elevation for all frequencies. This i frequently approximated by utilizing one end of th cavity to adjust the impedance at the fundamental an odd harmonics, while the other end can be used t provide a low impedance for the even harmonics. Thi procedure was used here, but for some frequencies no related in any simple fashion to the fundamental, th screen grid impedance was high enough to build u ufficient voltage so that feedback to the cathode via he screen-cathode capacity caused uncontrollable scillations. This mode of oscillation, in which electrons equire a transit time $T/2$ from cathode to anode, is recisely that envisaged in the original resnatron. Such n oscillation should be voltage sensitive, and a high nough voltage should suppress it. However, in this ase, the oscillation was so violent that it was impossible o get a voltage high enough so that the feedback was ot in phase. The grid was banded to reduce the screen athode capacity, and the oscillations were successfully ontrolled in this manner. In principle, the length of he screen can be adjusted to change the properties of he grid screen cavity, but such changes were ineffective n controlling the oscillation and were abandoned. In rder to help control low frequency oscillation (conected with the grid bias supply) an 8 μf condenser s used to bypass the dc grid bias lead near the tube.

The anode cavity is a λ/2 cavity with a movable horting plunger at the upper end for tuning. This uner is adjustable from outside the tube, the gear drive aving an insulating section to couple the motion to he parts operating at the high dc voltage. In the lower art of the cavity, three loops feed the output coaxial ine. The dc isolation choke, which accounts in part or the large tube dimensions, has in some of its outer omponents, diameters such that circumferential modes re possible. Whereas single loop excitation normally eads to excitation of the first θ mode, the three loops void the problem. Correct phasing of the loops at 200 nc was accomplished by maintaining reasonable nechanical accuracy.

Although the existence of the large isolation choke ncreases the vacuum volume and the area to be outassed, it has the advantage that any power leaking rom the isolation chokes is still contained in the vacum shell. With the more usual construction in which solation is accomplished by means of a choke joint in he external waveguide, the rf leakage would probably ave been too high to tolerate.

All major parts of the chokes and cavities are solid FHC copper with the exception of the control grids hich are nickel for purely mechanical reasons. (The opper proved to be so soft that it was difficult to andle the grid assembly without deforming it.) All oints are hard soldered, copper welded or bolted. No pecial care was taken to polish the surfaces. No rf eating problems have been encountered. Fig. 12 shows he control grid under construction.

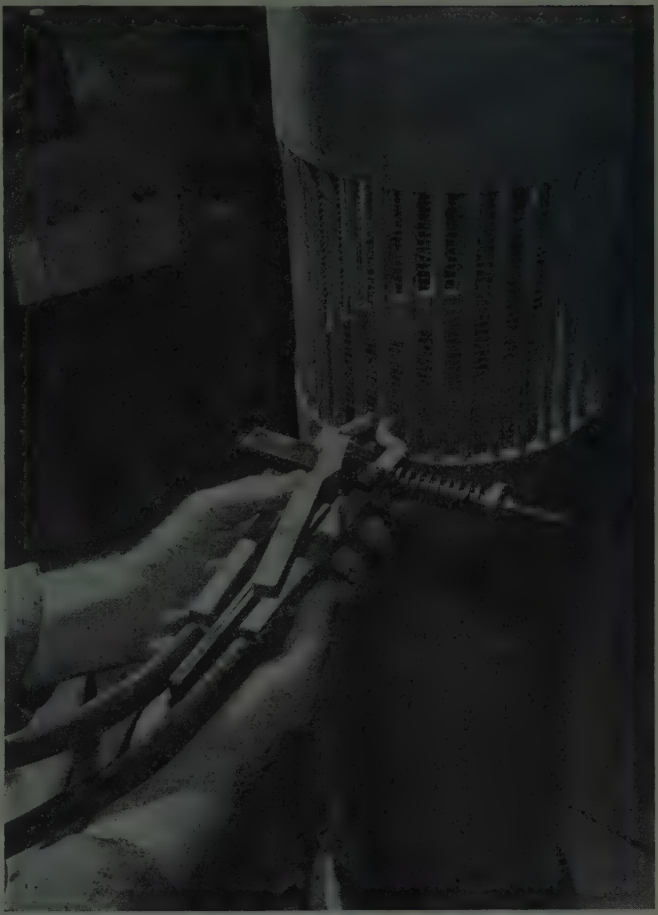


Fig. 12—Control grid under construction—tungsten wire spot welded to nickel grid bars.

MECHANICAL

It has been said that once the tube dimensions have een set, the remainder of the problem involves nechanical engineering. We were most fortunate in aving excellent cooperation both in the engineering nd in the construction of parts.

The anode is cooled by means of water circulating in opper tubes wound outside and soft soldered to the anode cylinder. (Hard solder would have been used had it been feasible.) The other tube elements are made of two coaxial cylinders baffled in such a way as to allow water to flow down one side, around the bottom and back up the other side. In the case of the control and screen grids, the grid bars form part of the flow circuit. There is, on the average, a temperature difference across the cylinder due to the in-out temperature difference of the water. In practice the water flow is high enough so that this differential is not troublesome. Water leaks are, however, a real problem with this type of construction.

As mentioned above, no special surface treatment is used other than a reasonably smooth machine finish. A polish would be worthwhile if it eliminated arcing during dc high-voltage outgassing. It is felt, however, that low-energy high-voltage arcing will condition the surface itself, and the length of time required is not appreciably lessened by polishing, since if a single arc occurs on a polished surface, a number of arcs will be needed to clean up the surface. In this tube, the arcing is fairly evenly split between the screen grid cylinders and the isolation choke. It is thought that the arcing in the choke takes place mainly during dc outgassing, whereas the arcing during operation occurs preponderantly near the beam in the screen grid region.

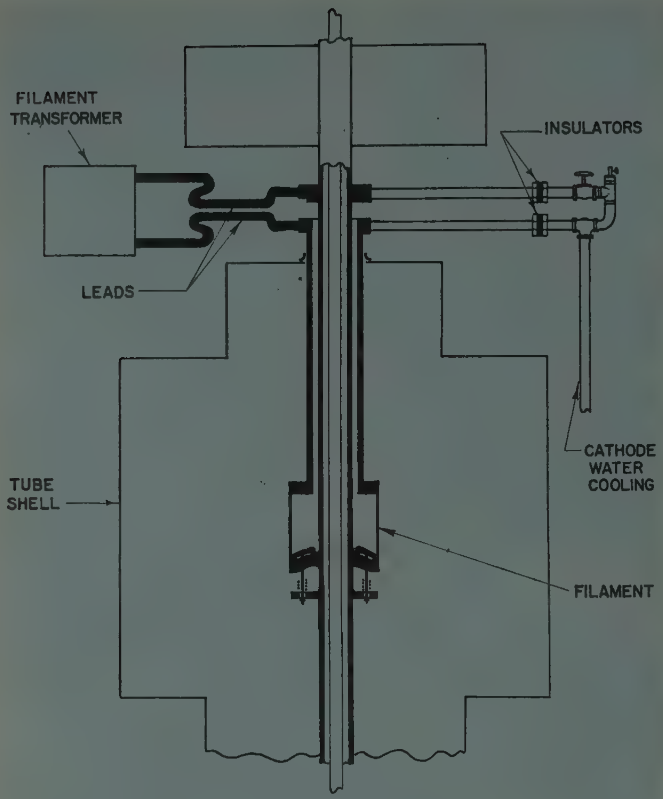


Fig. 13—Filament supply schematic.

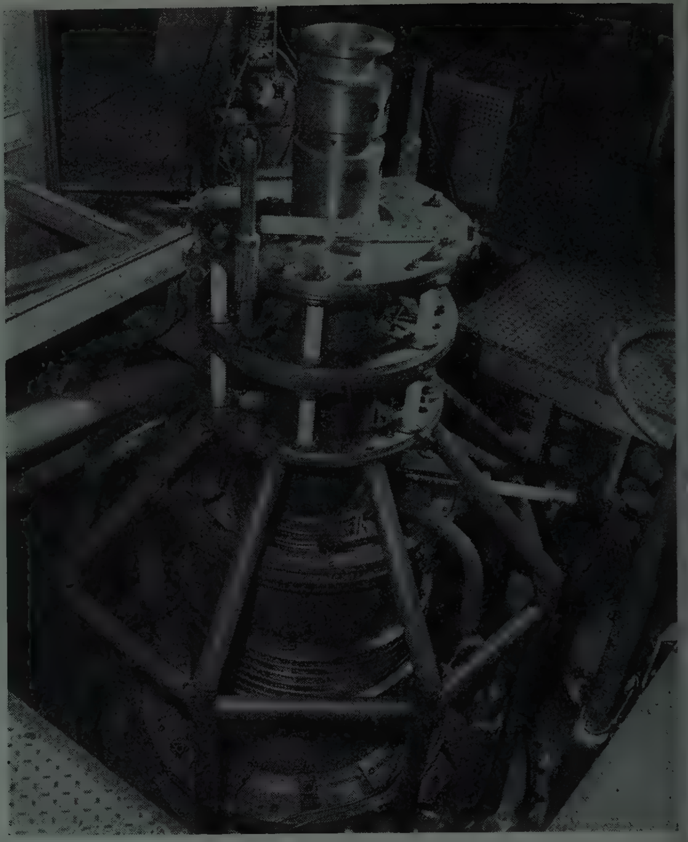


Fig. 14—Assembled tube without vacuum housing and part of the input coaxial line.

The filament connectors shown in Fig. 13 are heavy-bolted clamp-type connectors which not only provide contact through which 7000 amperes flow with negligible voltage drop, but also act as the water connectors to both ends of the cathode.

The vacuum system for each resnatron consists of a 1400 C.F.M.[7] oil-diffusion pump with a freon baffle. Each tube has its own diffusion pump but a common fore line is used. Air-operated manifold valves can isolate the tube from pumps and baffle, and are automatically set to do so in case of vacuum trouble. Up until now, Litton oil has been used in the diffusion pumps. After the system has been pumped for several weeks, the cold pressure is in the vicinity of 5×10^{-7} mm Hg. There is some indication that other pump oils are more desirable for use with lower-temperature filaments. All of these pressures are measured in the vacuum manifold, and the operating pressures in the vicinity of the filament are doubtless higher. O-rings, flat gaskets and Wilson seals are used depending on size and function. Periodic defrosting of the refrigerators (every two or three months) has been found necessary to prevent too much oil accumulating on the cold baffles.

The type of construction precludes any real bakeout. One might consider a steam-temperature bakeout by using steam in the water systems and such a treatment was used once. Normal O-rings (neoprene) are not cured sufficiently to withstand this treatment without deforming, and subsequent vacuum troubles completely nullify any gain made by the bakeout. Some tests indicated that a curing procedure for the O-rings and gaskets could be worked out, but it is not thought worthwhile at present.

The cleaning techniques are not complicated and cannot be greatly successful because of the contaminated atmosphere in the building. The standard procedure is to wipe all parts with a clean cloth soaked in acetone (or vythene), flush with C.P. acetone (or vythene) and then flush with alcohol. When it is necessary to handle parts, cloth gloves are used.

ALIGNMENT

The anode and screen are presumed to be perpendicular to the base plate. The anode can be rotated to align the fins with the screen bars. This procedure is carried out using, as alignment criteria, sights through holes drilled in the anode midway between the fins. (See Fig. 14.) The cathode and grid are aligned as a unit using gauges to determine concentricity and spacing; then the whole assembly is lowered into the tube and aligned with the screen by sighting through the holes in the anode. Adjustments are provided between the cathode and grid, and between the grid and screen, to adjust for vertical position as well as rotation. Because of the weights involved, assembly of all these nits is accomplished by means of heavy cranes and reat care must be taken to avoid damage to cathodes, rid bars, etc.

---

[7] Consolidated Vacuum Corp., M.C.F. 1400.

WATER-LOAD TESTS

During construction, and prior to using the resnatrons o drive the accelerator tanks, they were tested by unning them into waveguide water loads. These loads vere constructed from a 40-inch length of guide with a liagonal lucite sheet to contain the water. The water low was directed so as to prevent hot spots and to nsure adequate mixing. Several precautions were ound to be necessary before the loads would take the 3.5 megw of peak power which was eventually measured. It was found that the city water corroded the aluminum casing so badly that hot spots would develop at underwater surfaces and little steam explosions would occur. The surface of the aluminum was thoroughly cleaned and painted to prevent corrosion. The end plate had to be welded in place because of the difficulty of obtaining a waterproof joint and good electrical contact at the same time. Because of the short length of the water load, a susceptive post tuner was needed to match the load to the guide.

All tests were conducted with the load matched to the guide. Resnatron tuning adjustments were made to maximize the power to the load. After calibration, many of the measurements were made using resistive loop directional couplers rather than waiting for the water load to come to equilibrium.

Since we were concerned with power at only one frequency, the bandwidth was unimportant as long as the 300-μsec pulse was amplified with moderate fidelity. No measurements of loaded Q's were made. Although a certain amount of testing was required to determine that the loop size was satisfactory, this was essentially a cut and try method in which loops of various areas and shapes were tried until the ones giving maximum power were obtained. As a matter of fact, the original set of loops, based on very simple calculations (suggested by W. W. Salisbury) of fields in the cavity and the field induced in the loop, turned out to be the most satisfactory.

Typical power outputs and the operating conditions for the two electrode configurations are given in Table I.

TABLE I

	E_p kv	i_p amps	E_g kv	i_g amps	Power Gain	Power Output watts
Old design	40	33	−3.5	3.3	15	0.85×10^6
New design	70	81	−1	1.65	10	3.5×10^6

In practice, of course, the resnatrons are operated into the high-Q tanks. There was some question as to whether the tubes would operate as well into the high-Q load as they did driving the water load. For example, the effect of the substantial mismatch which is inevitable sometime during the tank buildup was unknown. Since the tanks were readily available and the coupling waveguide was already laid out, once the resnatrons produced power into the water load, it was very easy to connect the power output of the resnatrons to the cavity to be driven. Because of their size, the resnatrons were initially installed in the positions they would occupy when powering the accelerator. Leaving the resnatron tuning at the resistive load positions and tuning the transitions to the tank to the matched positions (determined with CW), it was found that the resnatron would deliver quite reasonable power to the high-Q circuit. To optimize the power, it was necessary to retouch the tuning. An automatic frequency control was available to keep the tanks in tune.[8]

The waveguide from the resnatron output involved one right-angle turn before a transition back to coax line, in order to feed a loop whose resistive component had been matched to the tank. No care had been taken to make the electrical distance from the tube to the tank a multiple of a half wavelength which is sometimes considered to be the ideal for such a system.

In general, it was found that the main gain in tuning was the change in build-up time that one could achieve by detuning the load. In general, the build-up is faster if the high-Q tank is detuned, and, in spite of the fact that the final level is not as high as for the on-tune case, it may be the most desirable mode of operation. Operation into the high-Q load was uneventful, and although no thermal power measurements were made into this water-cooled load, the power obtained was not far from that into a resistive load under the same conditions (using measured rf field strengths and the estimated shunt impedance to calculate power). For us the main criterion is whether protons of the correct energy are obtained from the accelerator, and not the absolute power output of the tube. From the tube engineering point of view, this may be undesirable, but from the accelerator point of view, it is the measure of success.

MAINTENANCE AND RELIABILITY

In operation, there are three resnatrons operating into high-Q tanks with a fourth acting as a driver for the other three. The power outputs required are approximately 3.5, 2.2, 0.6, and 0.6 megw. The tubes all operate off a common dc plate supply, and each is individually biased so that operation is class B or just on the class C side of this point. An arc in an individual tube will trip off the power supply and interrupt operation. From work done with the individual resnatrons, it has been observed that by far the greatest number of arcs occur during the rf pulse, and it is not felt that the use of dc on the plate decreases the reliability to any great extent. Each arc trips off the plate supply[9] and the outage time depends on how fast the vacuum recovers from the arc-produced gas. Normally the outage will not be more than 20 seconds. The principal rf arcing trouble has occurred at the output vacuum seal, and the addition of the shields indicated in Fig. 11 corrected the trouble. No multipactoring has been observed, perhaps because the most probable places are biased with dc voltages.

---

[8] E. A. Day, Featherstone, Johnson, E. E. Lampi, E. B. Tucker, and Williams, submitted to *Rev. Sci. Instr.* on Minnesota Linear Accelerator.

The loss of an individual filament makes disassembly necessary only if a cathode-grid short results. Resnatrons have been operated with as many as nine filament strands broken, no cathode grid shorts having developed; at other times we have not been so fortunate. Careful records of voltage and current for each resnatron filament show steps indicating loss of filament strands. Very recently, however, a tube with a new pantograph assembly operated for 900 hours without loss of a single filament strand. To date the operation of the resnatron has been a pleasant surprise.

Acknowledgment

The early work on the resnatron at Collins Radio Company was done by W. W. Salisbury, Drs. R. L. McCreary, P. I. Corbell, and W. J. Armstrong, while E. Phillips was responsible for design of some waveguide components. Much of the credit for the filament and pantograph design is directly attributable to the excellent cooperation of the RCA Power Tube Division, Lancaster, Pa. Dr. L. Garner, W. Parker, and W. Harbaugh were most cooperative in providing design information and samples.

This work was carried out as part of the accelerator program and was aided considerably by the advice, cooperation, and understanding of the Minnesota Linear Accelerator Group headed by Prof. J. H. Williams. The construction of parts was supervised by R. B. Thorness. The majority of the numerous assemblies and disassemblies were the responsibilities of L. Rawson, K. Menafee, W. Eckman, and D. E. Service. R. P. Featherstone aided in many ways. The encouragement and advice of Prof. D. H. Sloan has been of great value. To these and others who aided both directly and indirectly we acknowledge our indebtedness.

---

[9] R. P. Featherstone, C. Ling, and P. A. Cartwright, *Trans. AIEE*, vol. 72, pt. I, pp. 145–152; 1953.

Atmospheric Effects on VHF and UHF Propagation*

GEORGE H. MILLMAN†, SENIOR MEMBER, IRE

Summary—**This paper is mainly concerned with the effects of the troposphere and ionosphere on the propagation of vhf and uhf radio waves.**

Tropospheric refractive index profiles and ionospheric electron density models representative of average atmospheric conditions are presented.

Mathematical relationships are derived for calculating refraction effects, time delays, Doppler errors, polarization changes, and attenuation experienced by radio waves traversing the entire atmosphere.

I. Introduction

THE ADVENT of man-made satellites projected into outer space focuses attention on the problem of determining their true orbital paths as they circumvolve the earth. The prediction of orbital positions necessitates that a satellite must first be detected and then tracked. These functions can be performed either by optical means or by radio wave transmissions.

With regard to the use of radio waves in long-range detection and prediction, the limiting factor of system performance and capability is largely dependent upon the medium, or atmosphere, through which the waves are propagated. In the atmosphere, the regions which greatly influence and affect radio wave propagation are the troposphere and the ionosphere.

The effects brought about by the passage of waves through these regions manifest themselves as angular refraction, time delays, Doppler errors, polarization rotations, and attenuation. In the ensuing discussion, these phenomena are described and assessed with application to frequencies in the vhf and uhf range.

II. Atmospheric Models

A study of the effects of the atmosphere on radio wave propagation necessitates a knowledge of the height variation of the dielectric constant, or refractive index,

---

* Original manuscript received by the IRE, November 27, 1957; revised manuscript received, March 20, 1958. This work was supported by the Rome Air Dev. Center under Contract AF 30(602)-1514.

† General Electric Co., Syracuse, N. Y.

In the tropospheric and ionospheric regions. Since the magnitude of the dielectric constant is a function of such parameters as the geographic location on the earth, weather, time of day, and season of the year, it would be an overwhelming task to analyze completely atmospheric propagational effects under all parametric conditions. To simplify the analytical problem, atmospheric models representative of average conditions are employed.

The Troposphere

In the troposphere, the index of refraction which is a function of meteorological variables such as water vapor, air temperature, and air pressure, can be represented by

$$(n-1)\times 10^6 = \frac{a}{T}\left(p + \frac{b\epsilon}{T}\right) \qquad (1)$$

where n is the refractive index; T, the air temperature in degrees Kelvin; p, the total pressure in millibars; and ϵ, the partial pressure of water vapor in millibars. The first term, ap/T, applies to both optical and radio frequencies, while the second term, $ab\epsilon/T^2$, is the explicit water vapor relationship required only at radio frequencies.

According to Kerr,[1] the constants, a and b, are approximately equal to 79°K/mb and 4800°K, respectively. Campen and Cole[2] quote 74.4°K/mb and 4973°K as the values of a and b. Through consideration of various propagation experiments, Smith and Weintraub[3] arrive at the values of 77.6°K/mb and 4810°K.

The expression for the refractivity of air is independent of frequency in the 100–10,000-mc range. According to Smith and Weintraub,[3] this expression is considered to be valid to 0.5 per cent in $(n-1)\times 10^6$ units for frequencies up to 30,000 mc and normally encountered ranges of temperature, pressure, and humidity.

The analytical expressions of refractive index for a standard atmosphere utilized in this study were derived by Campen and Cole.[2] The refractive index of a completely wet (100 per cent relative humidity at all levels) standard atmosphere is approximated by the polynomial expression

$$N_w = 338 - 50.9Z + 4.39Z^2 - 0.245Z^3 + 0.0071Z^4 - 0.00006Z^5 \qquad (2)$$

where

$$N_w = (n_w - 1)\times 10^6. \qquad (3)$$

For a completely dry (zero per cent relative humidity at all levels) standard atmosphere, the refractive index is given by

$$N_d = 262 - 25.1Z + 0.92Z^2 - 0.016Z^3 + 0.0001Z^4. \qquad (4)$$

Eqs. (2) and (4) are valid for $0 \leq Z \leq 10$ km. Above 10-km altitude, the refractive index is assumed to decay exponentially as

$$N_{w,d} = N_{ow,od}e^{-h/25} \qquad (5)$$

where h is the altitude in thousands of feet, and N_{ow} and N_{od} are the values of N_w and N_d, respectively, at the earth's surface.

The Ionosphere

According to the theory of Eccles and Larmor,[4] the refractive index of a medium containing free electrons is given by

$$n = \sqrt{1 - \frac{4\pi N_e e^2}{m\omega^2}} \qquad (6)$$

where

N_e = electron density (electrons/cm^3),
e = electron charge (4.8×10^{-10} esu)
m = electron mass (9.1×10^{-28} gm),
ω = angular frequency of the incident wave (radians/second).

This relationship is valid when the earth's magnetic field and the collisions of electrons with ions and neutral particles are neglected.

The distribution of electron density with height under equilibrium conditions, as formulated by Chapman,[4] is

$$N_e = N_m e^{1/2[1-Z-e^{-Z}]} \qquad (7)$$

where N_m is the electron density at the level of maximum ionization and Z is the normalized height.

The normalized height is given by

$$Z = \frac{h - h_m}{H} \qquad (8)$$

where h_m is the height of maximum ionization density and H, the scale height which is defined as the height of the homogeneous atmosphere at a given temperature.

The distribution of electron densities under consideration is assumed to follow the Chapman form. The assumed magnitudes and levels of maximum ionization and scale heights given in Tables I and II are for both the daytime and nighttime ionospheric models.

---

[1] D. E. Kerr, "Propagation of Short Radio Waves," M.I.T. Rad. Lab. Ser., McGraw-Hill Book Co., Inc., vol. 13; 1951.

[2] C. F. Campen and A. E. Cole, "Tropospheric Variations of Refractive Index at Microwave Frequencies," Geophysical Res. Directorate, Air Force Surveys in Geophysics, No. 79, October, 1955.

[3] E. K. Smith, Jr. and S. Weintraub, "The Constants in the Equation for Atmospheric Refractive Index at Radio Frequencies," Central Radio Propagation Lab., Natl. Bur. of Standards, Boulder, Colo., Rep. No. 1938; September, 1952.

[4] S. K. Mitra, "The Upper Atmosphere," The Asiatic Soc. of Calcutta, Calcutta, India, 1952.

TABLE I

Daytime Parameters of Electron Density

Layer	H-(km)	h_m-(km)	N_m-(electrons/cm^3)
E	10	100	1.5×10^5
F_1	40	200	3.0×10^5
F_2	50	300	12.5×10^5

TABLE II

Nighttime Parameters of Electron Density

Layer	H-(km)	h_m-(km)	N_m-(electrons/cm^3)
E	10	120	0.8×10^4
F	45	250	4.0×10^5

In the upper atmosphere, electron collisions occur due to the presence of neutral particles and heavy ions and ultimately cause absorption of energy from the electromagnetic waves traversing the ionized medium. If it is assumed that the atmosphere is chemically homogeneous and isothermal, the angular collisional frequency of the electrons, ν, with the particles should obey the exponential law

$$\nu = \nu' e^{-(h'-h)/H} \tag{9}$$

where ν' is the collision frequency in radians per second at the altitude, h', and H is the scale height in the region.

The parameters which describe the electron collision frequency model utilized in this study are presented in Table III.

TABLE III

Collision Frequency Parameters

Layer	H-(km)	h'-(km)	ν'-(radians/second)
E	10	100	3×10^5
F	45	134	10^4

III. Atmospheric Refraction of Radio Waves

When electromagnetic waves are propagated through a medium whose dielectric constant or index of refraction is a varying function of the path, the waves undergo a change in direction or refraction. Since the earth's atmosphere is such a medium, errors are evidently introduced in the radar angular measurements of target position.

In the following analysis, only elevation-angle errors have been considered, even though horizontal refraction effects are definitely a source of azimuthal angle error.

To simplify the analytical problem, the troposphere and ionosphere are stratified into layers of constant refractive index. It is fully realized that this approach will render only approximate answers. However, since the profiles of refractive index in the atmosphere are not precisely known, a more exact mathematical solution appears unnecessary at this time.

A typical ray path trajectory of radio waves traversing the atmosphere in the vertical plane is shown in Fig. 1. It is assumed that 1) the troposphere extends to approximately 100,000 feet, with refractive index decreasing uniformly with height; 2) the ionosphere lies between 85–1000 km with a minimum refractive index at the level of maximum electron density; 3) free space or the region of unity refractive index prevails between the tropospheric and ionospheric regions. The elevation-angle error due to refraction, $\Delta\alpha_G$, is the angle between the apparent path direction and the direct line-of-sight path.

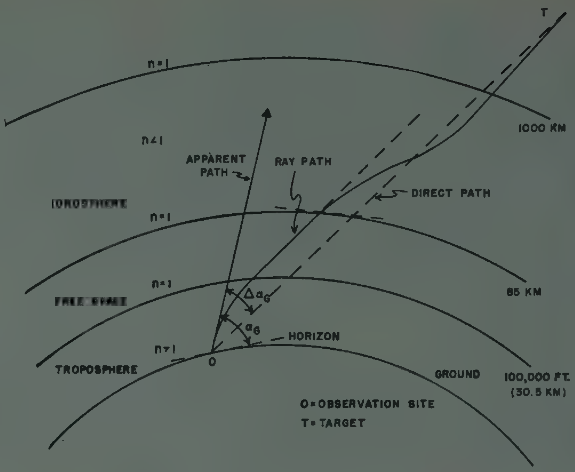


Fig. 1—Typical ray path trajectory.

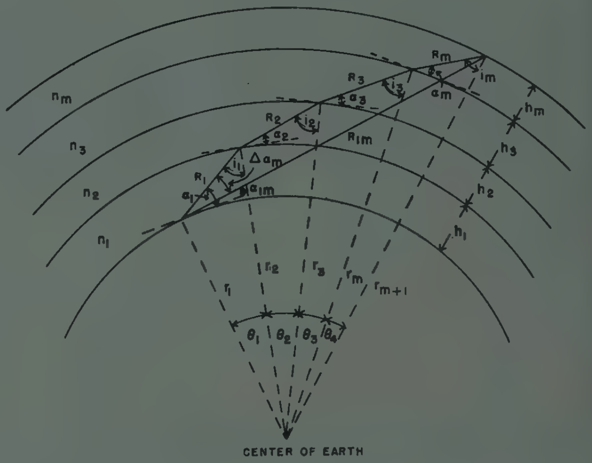


Fig. 2—Atmospheric layer stratification.

Tropospheric Refraction

Consider the stratified atmosphere, shown in Fig. 2, to consist of m layers of thickness, h_m. The index of refraction is assumed constant in each layer. A ray elevated at an angle, α_1, in layer 1 is incident at an angle, i_1, at layer 2.

From the law of sines, the angle of incidence, i_1, is found to be

$$\frac{\sin i_1}{r_1} = \frac{\sin\left(\dfrac{\pi}{2} + \alpha_1\right)}{r_2} \tag{10}$$

where r_1 is the radial distance from the center of the earth to the lower edge of layer 1 and $r_2=r_1+h_1$.

The angle that the ray makes with the horizon in layer 2, α_2, is readily obtainable from Snell's Law for a spherically symmetrical surface which states that

$$n_1 r_1 \cos \alpha_1 = n_2 r_2 \cos \alpha_2. \tag{11}$$

From (10) and (11) it is seen that the general expressions for α_m and i_m are therefore given by

$$\alpha_m = \cos^{-1}\left[\frac{n_{m-1} r_{m-1}}{n_m r_m} \cos \alpha_{m-1}\right] \tag{12}$$

and

$$i_m = \sin^{-1}\left[\frac{r_m}{r_{m+1}} \cos \alpha_m\right] \tag{13}$$

where

$$r_{m+1} = r_1 + \sum_{j=1}^{m} h_j. \tag{14}$$

Applying the law of sines again for the direct path, it follows that

$$\alpha_{1m} = \cos^{-1}\left\{\frac{r_{m+1}}{R_{1m}} \sin\left[\sum_{j=1}^{m} \theta_j\right]\right\} \tag{15}$$

where

$$R_{1m}^2 = r_1^2 + r_{m+1}^2 - 2 r_1 r_{m+1} \cos\left[\sum_{j=1}^{m} \theta_j\right] \tag{16}$$

and

$$\theta_j = \frac{\pi}{2} - \alpha_j - i_j. \tag{17}$$

The refraction-angle error, $\Delta\alpha_m$, which is the difference between the apparent elevation angle, α_1, and the true elevation angle, α_{1m}, is therefore given by

$$\Delta\alpha_m = \alpha_1 - \alpha_{1m}. \tag{18}$$

In the case of the troposphere, α_1 corresponds to the ground elevation angle, α_G, and r_1 corresponds to r_0, the radius of the earth.

The constants employed in the computation of refraction errors for the two tropospheric models were based on an assumed 18-layer stratified atmosphere. The layer thickness varied from 500 to 2500 feet below the 5000-foot level. Between this height and 50,000 feet and between the 50,000–100,000-foot region, the stratification thicknesses were 5000 and 10,000 feet, respectively.

As shown in Fig. 3, the refraction error increases with altitude and is a maximum for the standard atmosphere with 100 per cent relative humidity. For a target at 100,000 feet altitude and a propagating angle of 5°, an error of about 2.3 milliradians is obtained. For a 25° elevation angle, the refraction error decreases by a factor of 4.5. Comparing errors calculated for zero per cent with 100 per cent relative humidity, it is seen that under identical conditions the latter are about 1.5 times greater than the former.

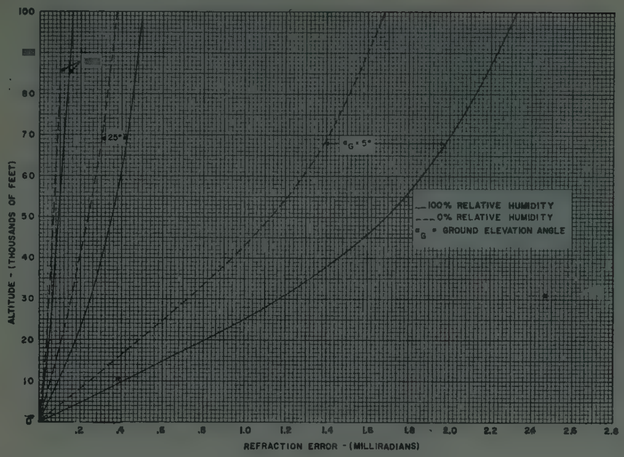


Fig. 3—Tropospheric refraction errors for a standard atmosphere.

Ionospheric Refraction

The preceding mathematical development is applicable to the ionospheric problem. It is necessary, however, to redefine the angle, α_1, as the ionospheric elevation angle, α_I, and the distance, r_1, which now corresponds to the distance from the center of the earth to the bottom edge of the ionosphere. Actually, $r_1=r_0+h_0$, where h_0 is the height of the ionosphere above the earth's surface.

For the daytime electron density model, the ionosphere was stratified into 11 layers varying in thickness from 5 to 50 km between the 85–250-km heights and from 100 to 200 km between the 250–1000-km region. In the case of the nighttime model, a 10-layer stratification was employed with thicknesses varying from 15 to 35 km between the 85–200-km level and from 100 to 300 km between 200–1000 km.

The refraction errors for the daytime and nighttime models of electron density are presented in Figs. 4 and 5 for 200 and 400-mc transmission frequency. It is evident that for identical propagating conditions the angle error decreases with the square of frequency.

It is noted that the angular error is a maximum in the vicinity of the maximum ionization. The effect of the E layer on refraction in comparison to the F layer, where the greatest deviation takes place, appears to be very slight. The daytime refraction error is approximately 2.7 times greater than the nighttime error. This compares favorably with the value of 3.1, which is the ratio of daytime-to-nighttime maximum density.

The realistic electron densities have been substituted by an idealistic model in which the electron densities are constant above the levels of maximum ionization. Thus, for the daytime model, 12.5×10^5 electrons/cm^3 are assumed to be present above 300 km and, for the

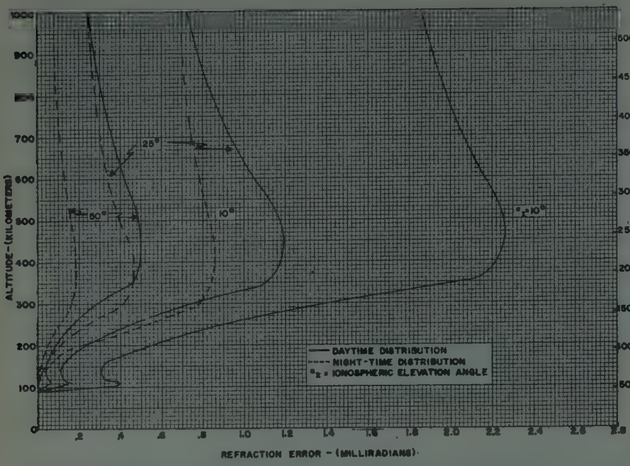


Fig. 4—Ionospheric refraction errors at 200 mc—decaying distribution of electron density above F-layer maximum.

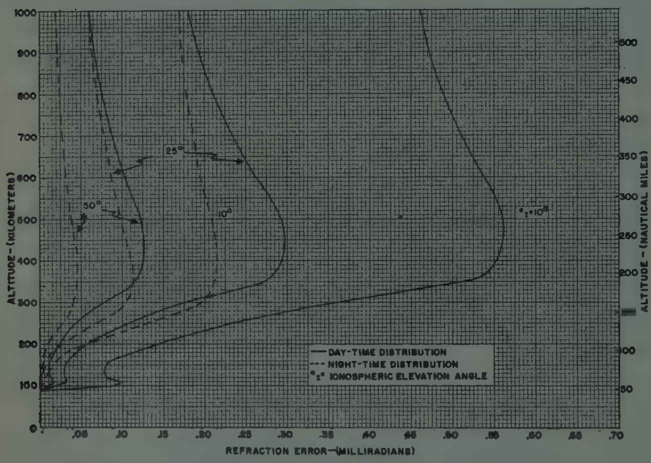


Fig. 5—Ionospheric refraction errors at 400 mc—decaying distribution of electron density above F-layer maximum.

nighttime model, 40.0×10⁴ electrons/cm³ above 250 km.

As indicated in Fig. 6, the refraction error increases with altitude, while, for the models of decaying electron density, the error is found to decrease at the high altitudes. Since the true electron density distribution above the F-layer maximum is not known, there is evidently a region of uncertainty in theoretically predicting ionospheric refraction errors.

IV. Time Delays in the Atmosphere

Since the velocity of electromagnetic propagation in the troposphere and ionosphere is slightly less than the assumed free space velocity, an error is produced in the range measurements of radar target positions. An additional source of error is the increase in the ray path length brought about by refraction. Both factors are taken into account in this investigation of tropospheric and ionospheric range errors.

Tropospheric Time Delay

Referring to Fig. 2, it is seen that the time of travel along ray path, R_1, is

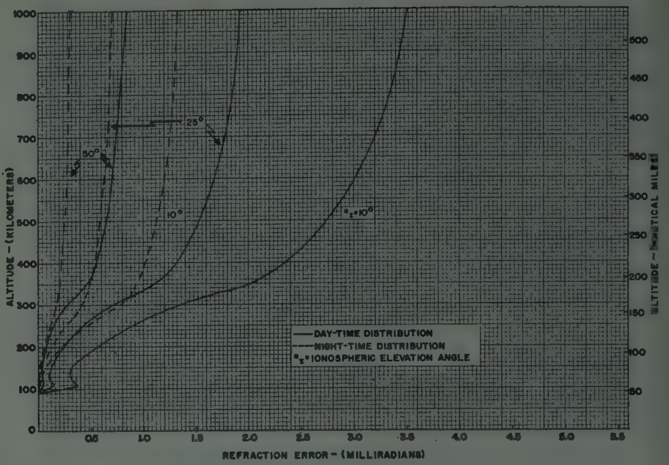


Fig. 6—Ionospheric refraction errors at 200 mc—constant distribution of electron density above F-layer maximum.

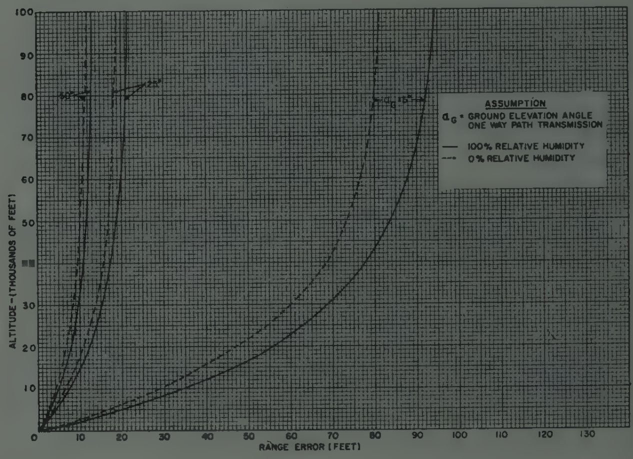


Fig. 7—Tropospheric range errors for a standard atmosphere.

$$t_1 = \frac{R_1}{V_{p1}} \tag{19}$$

where V_{p1} is the phase velocity in the first layer defined by

$$V_{p1} = \frac{c}{n_1} \tag{20}$$

and where c is the free space propagation velocity.

It follows, therefore, that the total time of flight of the refracted beam in the stratified layers becomes

$$t_t = \frac{1}{c} \sum_{j=1}^{m} n_j R_j. \tag{21}$$

Since the free space travel time of the unrefracted ray is

$$t_{1m} = \frac{R_{1m}}{c} \tag{22}$$

the range error reduces to

$$\Delta R = \sum_{j=1}^{m} n_j R_j - R_{1m} \tag{23}$$

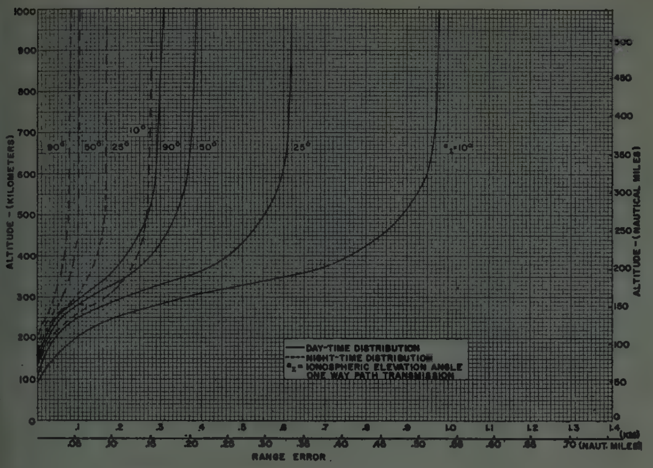


Fig. 8—Ionospheric range errors at 200 mc—decaying distribution of electron density above F-layer maximum.

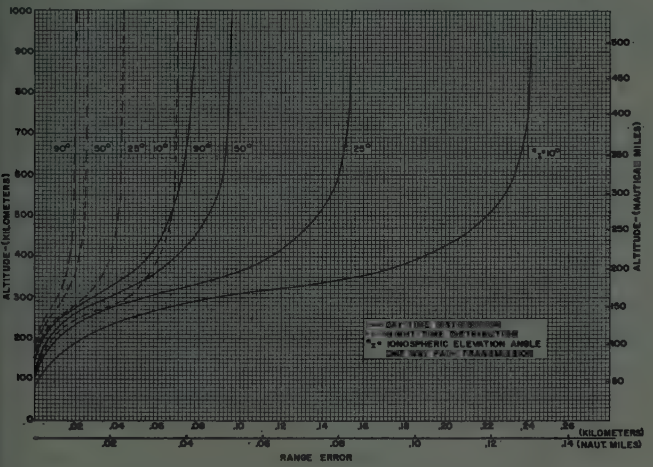


Fig. 9—Ionospheric range errors at 400 mc—decaying distribution of electron density above F-layer maximum.

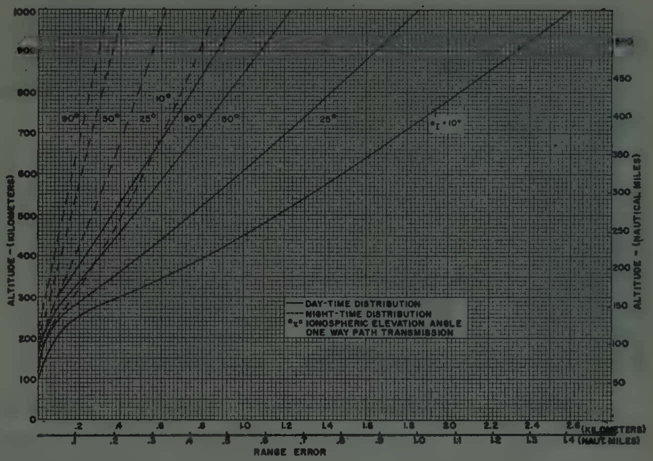


Fig. 10—Ionospheric range errors at 200 mc—constant distribution of electron density above F-layer maximum.

where the distance, R_j, is given by

$$R_j^2 = r_j^2 + r_{j+1}^2 - 2r_jr_{j+1} \cos \theta_j \tag{24}$$

and where R_{1m}, α_j, and θ_j are the parameters previously defined in Section III.

The tropospheric range errors plotted in Fig. 7 for the two standard atmospheric models are a direct function of the amount of relative humidity in the air, the value at zero per cent relative humidity being about 85 per cent of the value at 100 per cent relative humidity. Since the maximum, two-way path transmission, range error is on the order of 195 feet for a target elevated at an angle of 5°, it is therefore concluded that the troposphere has very little effect on propagational time delays.

Ionospheric Time Delay

The group velocity of a wave packet must be used when problems of pulsed electromagnetic waves are concerned. In the troposphere, the group and phase velocity are synonymous since, in the frequency range of interest, the index of refraction is independent of frequency. For the ionosphere, however, the refractive index of the medium is a function of the transmitted frequency.

In the simple case when the earth's magnetic field and electron collisions are neglected, the group velocity, V_g, is related to the phase velocity by

$$V_pV_g = c^2. \tag{25}$$

Since

$$V_g = nc \tag{26}$$

the total time of travel in the deviating medium becomes

$$t_t = \frac{1}{c} \sum_{j=1}^{m} \frac{R_j}{n_j}. \tag{27}$$

It follows that the range error is given by

$$\Delta R = \sum_{j=1}^{m} \frac{R_j}{n_j} - R_{1m}. \tag{28}$$

Figs. 8 and 9 are graphs of range error for the daytime and nighttime models of electron densities previously described. It is seen that: 1) the range error is a maximum during the daytime, increasing with low elevation angles; 2) the error is inversely proportional to the square of frequency; 3) the majority of the time delay occurs below the 500–600-km height. At 200 mc, for a two-way path transmission, the maximum error is on the order of 1.1 nautical miles. As shown in Fig. 10, this value is increased to 2.8 nautical miles when the distribution of electron density is assumed constant above the F-layer maximum.

V. Doppler Effects Due to the Atmosphere

Due to the propagational anomaly of refraction of radio waves traversing the atmosphere, an error is introduced in the determination of the line-of-sight or radial velocity of a moving target. This error results from the fact that the direction of the refracted ray at the target differs slightly from the fictitious line-of-sight or apparent path direction. The Doppler error, introduced by the incorrect assumption of the magnitude of the refractive index at the target location in the deviating medium, is believed to be indeterminate and is therefore not considered in this analysis.

It should be mentioned that, unlike the refraction and range errors, the Doppler errors are not cumulative. In other words, the total Doppler error, for a target traversing the ionosphere, is only the localized error at the specific point in the medium. The troposphere merely acts as a refractive medium.

Tropospheric Effect

A target, T, is traveling with a velocity, V, in an arbitrary direction in the refractive medium. The components of target velocity for the various orientations shown in Fig. 11 are

$$V_r = V \cos (\psi + \Delta\alpha_T) \tag{29}$$

$$V_d = V \cos \psi \tag{30}$$

$$V_a = V_d \cos (\Delta\alpha_G) \tag{31}$$

where V_r, V_d, and V_a are the components of V in the ray path direction, in the direct path direction, and in the apparent path direction, respectively. The angle, $\Delta\alpha_G$, is the refractive error angle while $\Delta\alpha_T$ is the angle between the ray path and the direct path at the target location.

The error introduced in the measurement of the target Doppler velocity, ΔV, is given by

$$\Delta V = V_a - V_r. \tag{32}$$

Expanding the cosine term of (29) and then substituting the resulting expression, together with (30) and (31), in (32), it follows that the velocity error can be written in the form

$$\Delta V = V \cos \psi [\cos (\Delta\alpha_G) - \cos (\Delta\alpha_T)] + V \sin \psi \sin (\Delta\alpha_T). \tag{33}$$

Since $\Delta\alpha_G$ and $\Delta\alpha_T$ are very small angles, the trigonometric functions can be expanded in a series. Neglecting higher order terms, it follows that

$$\Delta V \cong V \cos \psi \left[\frac{(\Delta\alpha_T)^2}{2} - \frac{(\Delta\alpha_G)^2}{2} \right] + V \sin \psi (\Delta\alpha_T). \tag{34}$$

Since the magnitudes of $(\Delta\alpha_T)^2$ and $(\Delta\alpha_G)^2$ are of the order of microradians, the target radial velocity component, $V \cos \psi$, can be neglected. Thus, to a first approximation

$$\Delta V \cong V \sin \psi (\Delta\alpha_T). \tag{35}$$

It is seen that the Doppler velocity error in the radial direction attributed to refraction is composed only of the tangential velocity component of target velocity, $V \sin \psi$. The error is a maximum when the velocity vector is perpendicular to the direction of the direct path, and is a minimum when the target is moving along the direct line-of-sight path.

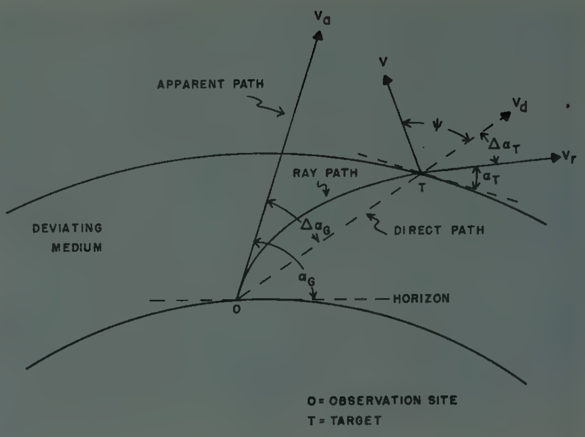


Fig. 11—Geometric orientation of target velocity components.

It is of interest to note that the identical expression for the Doppler velocity error, given by (35), would have been obtained if ΔV had been defined by

$$\Delta V = V_d - V_r. \tag{36}$$

In other words, the magnitude of the refraction error angle is not significant and can be neglected in this analysis.

According to the general concept of the Doppler effect, the reflection of a radio wave from a moving object results in a signal being returned to a fixed transmitting-receiving system whose frequency differs from the transmitted frequency. Analytically, this phenomenon is written as

$$f_d = -\frac{2V \cos \psi}{c} f \tag{37}$$

where f_d is the difference between the apparent reflected frequency, f', and the transmitted frequency, f.

The error, encountered in the measurement of the Doppler frequency, is, therefore, merely

$$d(f_d) = -\frac{2f}{c} \cos \psi dV \tag{38}$$

where it is assumed that f and ψ are errorless quantities. The term $\cos \psi dV$ is the component of target velocity error in the radial direction.

Substituting (35) in this relationship, it follows that the Doppler frequency error due to refraction is

$$d(f_d) = -\frac{2f}{c} V \sin \psi (\Delta\alpha_T). \tag{39}$$

With regard to the angle, $\Delta\alpha_T$, it can be readily shown from simple geometric considerations that

$$\Delta\alpha_T = \cos^{-1} \left[\frac{r_0}{r_0 + h} \cos (\alpha_G - \Delta\alpha_G) \right] - \cos^{-1} \left[\frac{n_G r_0}{n_T (r_0 + h)} \cos \alpha_G \right] \tag{40}$$

where n_G and n_T are the refractive indexes at the ground

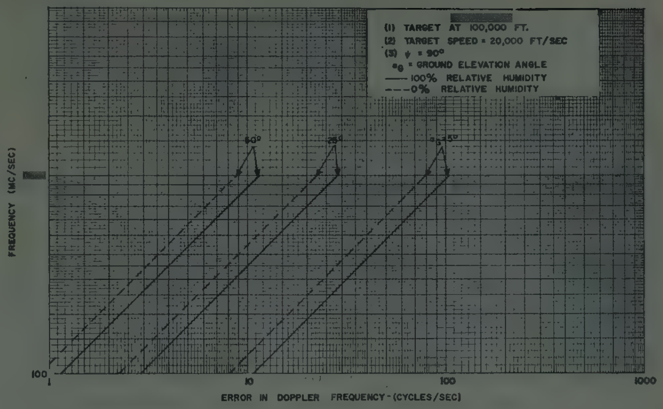


Fig. 12—Doppler frequency error in the troposphere for a standard atmosphere.

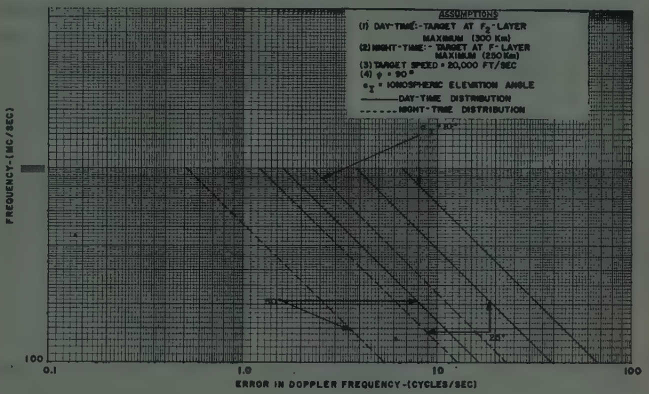


Fig. 13—Doppler frequency error in the ionosphere.

and target, respectively, and h is the target height above the earth's surface. To a first approximation, the refraction error, $\Delta\alpha_G$, can be neglected for elevation angles greater than 3°.

For an assumed target speed of 20,000 feet/second and $\psi = 90°$, the maximum Doppler frequency errors are plotted in Fig. 12, for the two tropospheric models of refractive index. The values of $\Delta\alpha_T$ used in these calculations are derived for a target at an altitude of 100,000 feet where n_T is approximately unity. It is seen that the greatest error occurs for the standard atmosphere with 100 per cent relative humidity. The error is directly proportional to frequency and, at 200 mc and 5° elevation angle, the maximum error is approximately 21 cps.

Ionospheric Effect

The mathematical derivation of the Doppler frequency error presented above is valid for the ionospheric problem. However, in applying (40) to conditions in the ionosphere, the following modifications are required: 1) the radius of the earth, r_0, is replaced by $r_0 + h_0$ where h_0 is the height of the lower edge of the ionosphere above the earth's surface; 2) the target height, h, is measured vertically from the lower edge of ionosphere; 3) the ground refractive index, n_G, now becomes n_I, the index of refraction at the entrance into the ionosphere, which, for all practical purposes, is unity; 4) the ground elevation angle, α_G, is replaced by the ionosphere elevation angle, α_I. An evaluation of the angle, $\Delta\alpha_T$, reveals that it is a maximum at the level of maximum ionization density and is frequency dependent, its magnitude varying approximately with the inverse square of frequency.

From the results given in Fig. 13, it is seen that the Doppler frequency error is a maximum during the daytime and at low elevation angles. For an assumed target speed of 20,000 feet/second and $\psi = 90°$, the error, at 200 mc and at an ionospheric elevation angle of 10° (this is the minimum angle that a ray makes with the tangent at an ionospheric stratified surface) is about 33 cps. For the nighttime, under similar conditions, the error is only 11 cps. It should be noted that, for the ionosphere, the Doppler error is inversely proportional to frequency.

VI. Ionospheric Polarization Effects

When a plane polarized radio wave enters the ionosphere, it separates into two independent wave components, both, in the general case, elliptically polarized with opposite senses of rotation. This phenomenon is the result of the electromagnetic waves interacting with the electrons in the ionosphere, which is encompassed in the earth's magnetic field. The two waves progress inside the ionized medium with different speeds. The phase relationship between the two waves is continuously changing as the ionosphere is traversed. On leaving the ionosphere, the waves recombine. The one significant alteration in the physical properties of the resultant wave is that the polarization of the emergent wave is different from the original wave.

Mathematical Derivation

Consider two sinusoidal progressive waves of the form

$$a_1 e^{j(\omega t - \gamma_1 s)} \qquad a_2 e^{j(\omega t - \gamma_2 s)}$$

where γ_1 and γ_2 are the phase constants defined by

$$\gamma_{1,2} = \frac{\omega}{V_{p1,2}}. \tag{41}$$

The difference in phase between the two waves traversing a distance, ds, is given by

$$d\phi = (\gamma_1 - \gamma_2) ds. \tag{42}$$

Utilizing (20) and (41), it follows that the total phase shift for a two-way propagating path is

$$\phi(s) = \frac{2\omega}{c} \int_{s_1}^{s_2} \Delta n ds \tag{43}$$

where s_1 and s_2 are the limits of the path, and where $\Delta n = n_1 - n_2$. In terms of a vertical height variable, this expression becomes

$$\phi(h) = \frac{2\omega}{c}\int_{h_1}^{h_2} \Delta n f(h) dh \tag{44}$$

where

$$f(h) = \frac{r_0 + h_0 + h}{\sqrt{(r_0 + h_0 + h)^2 - [(r_0 + h_0) \cos \alpha_I]^2}} \cdot \tag{45}$$

According to the theory of propagation of electromagnetic waves through an ionized medium in the presence of an external magnetic field (Magneto-Ionic Theory), the refractive index of the medium is a complex function of such parameters as the frequency of the wave, the electron density, and the electron collisional frequency.[4] For transmission frequencies above 100 mc the effects of electron collisions and layer critical frequencies can be neglected. Thus, based on these assumptions, the difference in the refractive indexes for transverse propagation (*i.e.*, the earth's magnetic field is perpendicular to the direction of propagation), becomes

$$\Delta n \cong \frac{\omega_c^2 \omega_H^2}{2\omega^4} \tag{46}$$

where

$$\omega_H = \frac{\mathcal{H} e}{mc}, \qquad \omega_c^2 = \frac{4\pi N_e e^2}{m} \tag{47}$$

and where $\mathcal{H}$ is the magnitude of the magnetic field in gauss. The other quantities in these expressions are defined by (6).

Substituting (46) and (47) in (44), the total phase shift simplifies to

$$\phi(h) = \frac{e^4}{2\pi^2 m^3 c^3 f^3}\int_{h_1}^{h_2} N_e f(h) \mathcal{H}^2 dh. \tag{48}$$

Similarly, for longitudinal propagation (*i.e.*, the earth's magnetic field is parallel to the direction of propagation), it can be shown that

$$\Delta n \cong \frac{\omega_c^2 \omega_H}{\omega^3} \cdot \tag{49}$$

It follows that the total phase shift becomes

$$\phi(h) = \frac{2e^3}{\pi m^2 c^2 f^2}\int_{h_1}^{h_2} N_e f(h) \mathcal{H} dh. \tag{50}$$

It should be noted that the limits of integration are in the same units as the free space velocity, c, and that the frequency, f, is in cps. Eqs. (48) and (50) can be readily integrated by numerical methods.

The phase change between the two magneto-ionic components, or polarization shift, for the two modes of propagation, are plotted in Figs. 14 and 15. The calculations were based on an assumed constant $\mathcal{H}$ of 0.6 gauss.

It is evident that the greatest polarization shifts occur, 1) when the direction of propagation is parallel to the earth's magnetic field, 2) during the daytime when the total electron content in the ionosphere is a maximum, 3) at low angles of propagation. In addition, it is seen that, for longitudinal propagation, the ionospheric polarization shift is inversely proportional to the square of frequency.

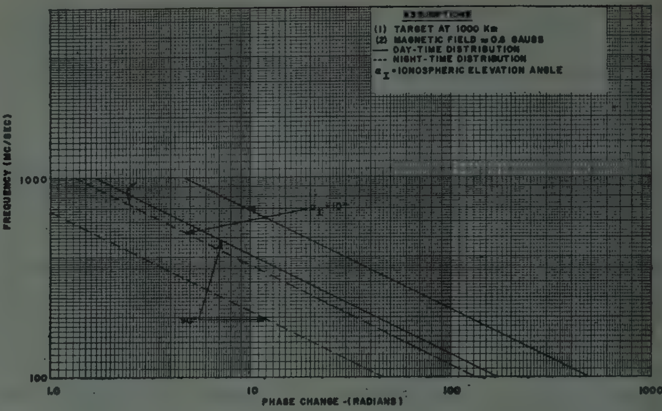


Fig. 14—Phase change between two magneto-ionic components—two-way path transmission—longitudinal propagation.

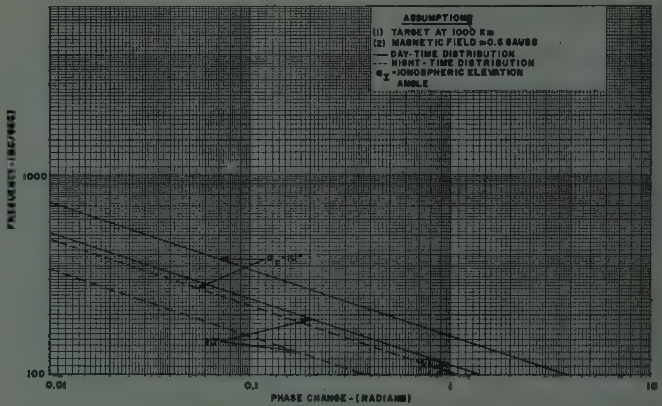


Fig. 15—Phase change between two magneto-ionic components—two-way path transmission—transverse propagation.

At 200 mc, a maximum phase change of approximately 120 radians can be anticipated as compared to a value of 0.5 radian for propagation perpendicular to the earth's magnetic field.

Assuming identical propagational conditions, the polarization shift during the daytime is approximately 3.5 times greater than during the nighttime.

VII. ATMOSPHERIC ATTENUATION OF RADIO WAVES

Tropospheric Attenuation

The absorption of radio waves in the lower atmosphere is the result of the presence of both free molecules and suspended particles such as dust grains and water drops condensed in fog and rain. In a noncondensed atmosphere, oxygen and water vapor are the substances which cause absorption.

Theoretical calculations of the anticipated absorption of electromagnetic waves by oxygen and water vapor have been made by Van Vleck.[1] His values of

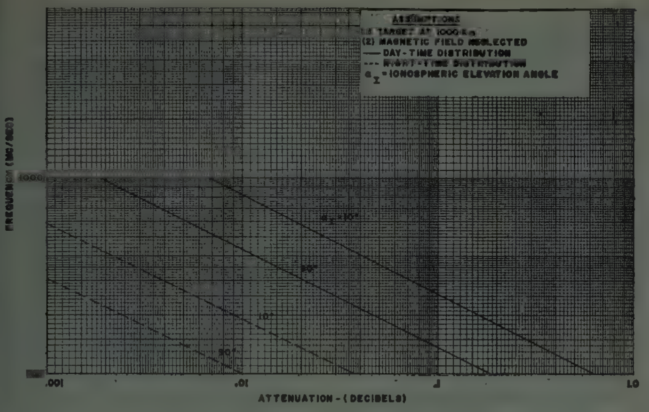


Fig. 16—Ionospheric attenuation—one-way path transmission.

the decay constant of oxygen at frequencies of 300 mc, 1000 mc, 3000 mc, and 10,000 mc are 0.0014 db/km, 0.0050 db/km, 0.0066 db/km, and 0.0072 db/km, respectively. The amplitude of the radio wave decreases at the rate of $10^{-0.05\gamma L}$ where L is the effective path length and γ is the decay constant. Assuming that the oxygen content is effective to an altitude of 50,000 feet and that the radar antenna beam is elevated at an angle of 5°, then the radiation traverses a distance of 156 km in this medium. This results in a two-way path attenuation, at 300 mc, of about 0.44 db, which is in addition to the free space attenuation.

At temperate latitudes, the water vapor decay constant at 3000 and 10,000 mc may be as high as 0.00004 db/km and 0.00066 db/km, respectively. It is therefore quite apparent that, for frequencies in the vhf and uhf range, the absorption by water vapor is insignificant.

Ionospheric Attenuation

An electromagnetic wave passing through an ionized medium imposes a periodic force on the electrons, causing them to vibrate. The absorption of signal energy occurs when the electrons, colliding with other particles, are forced to give up some of their energy to these particles.

The total attenuation, A, is given by the integral

$$A = \int_{s_1}^{s_2} k\,ds \tag{51}$$

where the limits of integration are the limits of the path and where k is the absorption coefficient of the medium defined by

$$k = \frac{N_e e^2 \nu}{2\pi c n m f^2}. \tag{52}$$

This expression is based on the assumption that the earth's magnetic field is neglected and that the transmitted frequency is much greater than the electron collision frequency,[4] the latter being valid for frequencies in the vhf range.

Substituting (9) and (52) in (51) and assuming non-deviation type of absorption, $n \cong 1$, the total attenuation becomes

$$A = \frac{e^2 \nu'}{2\pi c m f^2} \int_{h_1}^{h_2} f(h) N_e e^{-(h'-h)/H} dh \tag{53}$$

where the path differential is expressed in terms of the height differential.

The total attenuation for waves traversing the ionosphere is plotted in Fig. 16. It is seen that the attenuation is inversely proportional to the square of frequency, with daytime absorption being considerably greater than the nighttime effect. The maximum total daytime attenuation, at a frequency of 100 mc, is approximately 1.28 db. It thus appears that, under normal conditions, ionospheric attenuation should be negligible at frequencies above 100 mc.

VIII. CONCLUSIONS

The propagational errors considered in this study are representative of average atmospheric conditions. These errors can be compensated for when the distribution of electron density in the ionosphere and the variation of dielectric constant in the troposphere are known. Although the general magnitude of these parameters can be obtained through the use of vertical incident ionospheric soundings and meteorological observations taken in the near vicinity of a radar installation, such measurements do not describe the true conditions along the path travelled by the radio waves. It is fully realized that utilization of these data will only partially correct for the slowly-varying component of atmospheric errors. The instantaneous fluctuations about the mean of propagational errors which are the result of inhomogeneities in the atmosphere do not appear to be compensative at this time.

* * *

Atmospheric Noise Interference to Medium Wave Broadcasting*

S. V. CHANDRASHEKHAR AIYA†, SENIOR MEMBER, IRE

Summary—**A brief description is given of the typical tropical thundercloud and the electrical discharges associated with it. The discharge that contributes significantly to noise in the medium waveband is described in greater detail. There follows a systematic physical analysis of how the atmospheric noise impulse as heard by the ear arises and how it causes annoyance to the listener of broadcast programs. Hence, criteria are developed both for the measurement and estimation of atmospheric noise in the band. The method of analysis is similar to the one adopted by the author in a previous communication on atmospheric noise interference to short wave broadcasting.**

The results of the investigation are expected to hold over the frequency range, 0.23 to 2.5 mc.

INTRODUCTION

THE medium waveband, as ordinarily understood, extends from 0.3 to 3.0 mc. In this band, atmospheric noise is the principal source of interference to signaling systems. This is particularly so in the tropics, where atmospheric noise is high and man-made noise is low due to the under-developed nature of the countries situated therein. Broadcasting is the most important service for which frequencies are at present allocated in the band, and this paper examines the interfering effect of atmospheric noise on this one specific service.

The method of analysis adopted in the paper is similar to what has been reported in a previous communication.[1] Problems already discussed are briefly described when absolutely necessary. Detailed discussion has been restricted to those aspects of analysis in which this paper differs from the previous one. Such differences arise because the discharge that gives rise to noise in the medium waveband differs from the one responsible for noise in the short waveband.

NOISE INTERFERENCE

Discharges associated with lightning radiate impulses. The different Fourier components of the impulses travel through space like other radio waves and those lying within a bandwidth, B, at a frequency, f, are picked up by the receiver and finally produce the acoustic impulse that is heard through the loudspeaker. The waveform of this acoustic impulse gets superposed on the waveform of the actual program and causes annoyance to the listener.

As the physical parameters associated with lightning discharges show statistical variations, both the measurement[2] and the estimation[3] of atmospheric noise must have a suitable statistical basis. An idealized statistically valid representation of the phenomenon has already been defined as the one obtained by the assignment of median values to the different physical parameters associated with the phenomenon and this has been called a "typical" case.[1] This concept is adopted for this paper also.

An objective noise meter which simulates the typical human ear, and thus properly measures the interfering acoustic impulse, has already been described and discussed.[1,2,4] Its essential characteristics are summarized in Table I.

TABLE I
CHARACTERISTICS OF THE OBJECTIVE NOISE METER

1) Receiver	a) superheterodyne receiver with a bandwidth of 6 kc at 6 db down
	b) efficiency of rectification of modulation to be 0.9
	c) af output to be fed to the output unit
2) Output unit	a) charging time constant = 0.01 second
	b) discharging time constant = 0.5 second
	c) meter time constant = 0.2 second
	d) flat frequency response from 100 to 5000 cps
	e) logarithmic response for overload protection
3) Calibration	a) continuous signals
	b) modulation—30 per cent
	c) modulating af to be 400 cps

If E_{30} is the noise field strength as obtained with the calibration described in Table I, it can be converted to the noise field strength E_m, corresponding to a calibration using signals modulated to a depth, m, by the following equation:[5]

$$E_m = E_{30} \cdot \frac{0.3}{m} \cdot \tag{1}$$

The noise field strength is measured by the noise meter described in Table I. The data are collected and assessed on a statistical basis to deduce the median value of noise at a particular frequency for a particular sector of day for a season, and this is called the noise level. This noise level can be estimated by knowing the

---

* Original manuscript received by the IRE, January 20, 1958; revised manuscript received, March 31, 1958.

† L. D. College of Engineering, Ahmedabad 9, India.

[1] S. V. C. Aiya, "Atmospheric noise interference to short-wave broadcasting," PROC. IRE, vol. 46, pp. 580–589; March, 1958.

[2] S. V. C. Aiya, "Measurement of atmospheric noise interference to broadcasting," *J. Atmos. Terr. Phys.*, vol. 5, pp. 230–242; September, 1954.

[3] S. V. C. Aiya, "Noise power radiated by tropical thunderstorms," PROC. IRE, vol. 43, pp. 966–974; August, 1955.

[4] S. V. C. Aiya and K. R. Phadke, "Atmospheric noise interference to broadcasting in the 3 mc band at Poona," *J. Atmos. Terr. Phys.*, vol. 7, pp. 254–277; October, 1955.

[5] S. V. C. Aiya, "Conversion data for atmospheric noise interference measurements," (to be published).

mean center of thunderstorm activity and the laws of propagation, if the power which corresponds to the equivalent acoustic impulse can be calculated from lightning discharge data.[4] In evaluating the acoustic impulse and the equivalent power radiated from lightning discharges, it is necessary to take note of the fact that, so far as the ear is concerned, it is the maximum amplitude of sound, averaged for 0.001 second that measures impulsive noise and that the over-all effect observed over a period of 0.2 second is equivalent to continuous sound.[1]

In view of what has been explained above, the principal objects of this paper are 1) to indicate clearly the type of discharge associated with lightning that radiates noise in the medium frequency band, 2) to evaluate the characteristics of the interfering acoustic impulse that the noise meter measures and, hence, 3) to calculate the equivalent source power corresponding to the measured acoustic impulse. The sections that follow are devoted to examining the three problems in the order indicated. Finally, a concluding section briefly reviews the entire problem.

THUNDERSTORMS

Thunderstorms are localized thermodynamic processes in the atmosphere accompanied by electrical discharges. The growth and decay of thunderstorms as noise radiators have been investigated[6] in the tropics. It is found that a thunderstorm gradually builds up after local noon and reaches its peak activity by evening. This peak activity lasts three to six hours over land masses and longer over the sea. After peak activity, there is a drop and then a decay prior to sunrise. Generally, the activity is over within two hours after sunrise except for thunderstorms over the sea. Further discussion here is restricted to the period of peak activity of a thunderstorm.

During peak activity, a thunderstorm radiates at least ten flashes per minute and each flash lasts 0.2 second. In any typical thunderstorm, all flashes are intermittent and consist of four separate strokes. In between such strokes, slow electrical processes occur but they are not of importance for noise radiation in the short and medium wavebands. The physical nature of a stroke is as follows. There is probably a pilot streamer. This is followed by a leader streamer which is referred to here as the leader. This leader is followed by a recoil of low intensity and long duration when the discharge occurs in the cloud only. When the discharge strikes the ground, there is a return stroke of great intensity and short duration in place of the recoil occurring in cloud discharges.

All leaders in cloud discharges are discontinuous and consist of a number of steps following each other in time sequence. The growth of current during a discharge in a step gives rise to the radiation of an impulse and a stepped leader, therefore, radiates a train of impulses. The first leader in a cloud-to-ground stroke is a stepped leader but the greater part of the subsequent leaders is not stepped and they are often called dart leaders. The return stroke, the recoil, and the unstepped portion of dart leaders do not radiate any significant power in the short and medium wavebands.[7] It follows that the steps in the stepped leaders are the principal sources of noise in the short and medium wavebands. For a clear understanding of the distinction between the discharges responsible for noise in these two bands, it is necessary to examine the processes involved in the different types of stepped leaders. For this purpose, a description of the typical tropical thundercloud and the associated leaders is essential; this is given in the following sections.

THE TROPICAL THUNDERCLOUD

The data collected on the several aspects of lightning discharge by several methods in different parts of the world during different periods of the day have been critically examined and the essential characteristics of importance to noise deduced.[7] This section and the two that follow contain a factual summary of the results to the extent necessary for this paper.

Electrical discharges associated with lightning are basically discharges in the air at certain pressures and with a certain percentage of moisture. In certain cases, this discharge takes place in an atmosphere of charged particles and so on. But, the phenomenon is essentially the same at all latitudes. Differences, if any, arise from the fact that the height of the cloud base above mean sea level varies with latitude due to the variation of the the height of tropopause. The condition necessary for a discharge to strike the ground is that the cloud base is within a certain maximum distance from the ground. This implies that, for a discharge to strike the ground, the height of the cloud base above mean sea level depends on the altitude of the place.

A pictorial view of a typical tropical thundercloud is given in Fig. 1. The cloud base is about 4 km above mean sea level and the actual cloud extends to a height of about 14 km. Accumulation of positive and negative charges is as shown in the figure. Positively charged regions are not well defined and the spread of positive charge is diffuse. The negatively charged region is well defined and there is practically uniform concentration of charge.

Ordinarily, cloud discharges occur from the negatively charged regions and involve a length of about 1 km of the negatively charged region per stroke. It must be pointed out that this cloud discharge does occur even when the discharge is from the cloud to the air or to ground, but, in such cases, it is mostly a discharge from the negative region to the bottom positive region. That

---

[6] S. V. C. Aiya, C. G. Khot, K. R. Phadke, and C. K. Sane, "Tropical thunderstorms as noise radiators," *J. Sci. Ind. Res.* (*India*), vol. 14B, pp. 361–376; August, 1955.

[7] S. V. C. Aiya, "Atmospheric noise radiators," (to be published).

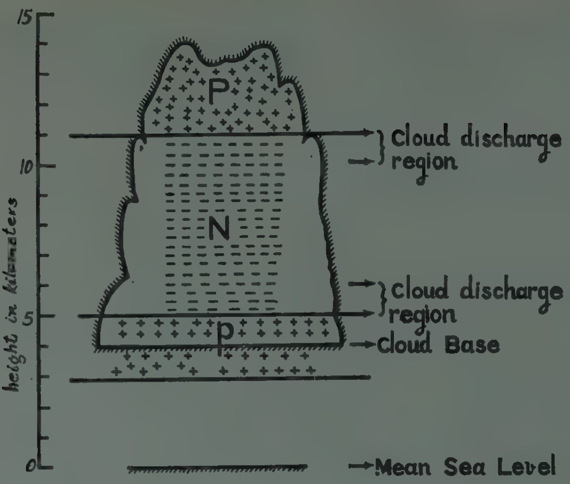


Fig. 1—A typical tropical thundercloud.

is, the cloud discharge is always there, either as part or whole of the discharge in all discharges.

A cloud discharge involves a length of about 1 km of the negatively charged region and $1/\sqrt{2}$ of this length, *i.e.*, 0.71 km, disappears after each stroke and this process goes on until the middle of the negatively charged region is reached. Since the latter is about 3 km from the ends, ordinarily, four strokes should be expected per typical flash as observed.[8] Since the negatively charged region extends over a length of 6 km or more, there is always a possibility of 10 strokes per flash in very exceptional cases. These statements hold for all discharges.

We now proceed to examine the details of a cloud discharge. It has already been pointed out that a stroke in such a discharge consists of a leader followed by a recoil. All such leaders are stepped and probably involve a length of 1 km of the negatively charged region, the successive leaders in a flash arising ordinarily from higher and higher regions. In each step, it is the growth of current in a discharge that gives rise to significant radiation. This growth can be represented by

$$I = I_0(1 - e^{-\delta t}) \tag{2}$$

where, I_0 is the peak current. δ is *similar* to the inverse of the relaxation time as defined by Gunn[9] and is given by

$$\delta = 4\pi\lambda \cdot 10^9 \tag{3}$$

where λ is the electrical conductivity of the region in electrostatic units (esu). It follows, therefore, that δ varies and is not constant. However, in calculations involving total vertical lengths of 1 or 2 km, it is reasonable to assume an average value for δ. As reliable conductivity measurements within the cloud are not available, it becomes difficult to calculate δ for cloud discharges.

Peak electric fields arise from the maximum rate of change of current, X, and this is given by

$$X = (dI/dt)\ \max = I_0 \cdot \delta. \tag{4}$$

The different parameters associated with a step in a cloud discharge have been discussed and given elsewhere.[8] A step radiates an impulse and, therefore, a stepped leader radiates a train of impulses. Since there are four strokes to a flash, a cloud discharge radiates four trains of impulses. A Fourier analysis of an impulse radiated by a step shows that it consists of a large number of components of different amplitudes and frequencies. The most important question to be examined is whether all the Fourier components of the impulse travel out of the small region in which the step makes its appearance. This is discussed briefly below.

A cloud discharge is confined to the negatively charged region in the cloud marked N in Fig. 1. An intense electric field, exceeding the disruptive strength of the dielectric, initiates the discharge and the appearance of steps. Because of these disturbed conditions, parts of the N region around the step have characteristics different from the rest of the N region. This is best described by saying that a "pocket" is created in the N region when a step appears. This pocket exists for a very short time but the important point to remember is that it exists for a period longer than the time taken by the step to radiate an impulse. In the Appendix it is shown that this pocket behaves in a manner *similar* to a waveguide and cuts off radiation at all frequencies below 2.5 mc. It follows, therefore, that a cloud discharge contributes to noise only at frequencies above 2.5 mc.

Cloud-to-Ground Discharge

When the height of the cloud base is of the order of 2.2 km from the ground, conditions are favorable for a cloud-to-ground stroke. In such a case, each of the four strokes consists of a leader and a return stroke. The first leader to ground is shown in Fig. 2. The literature on lightning discharges is full of terms like alpha leaders, beta leaders, etc. To avoid confusion, an entirely new nomenclature is adopted here. A typical stepped leader to ground has three distinct stages which are given below.

Stage I

This occurs in the negatively charged region and is identical with what has already been described as a cloud discharge. This stage does not contribute to noise in the medium waveband up to 2.5 mc.

Stage II

This occurs in the lower positively charged region; *i.e.*, partly in the cloud and partly in the air. The different parameters associated with steps in this stage are identical with those of stage I. But this stage lasts

---

[8] B. F. J. Schonland, "The lightning discharge," in "Handbuch der Physik," ed. S. Flugge/Marburg, Springer-Verlag, Berlin, Germany, vol. 22, pp. 576–628; 1956.

[9] R. Gunn, "The electrification of precipitation and thunderstorms," Proc. IRE, vol. 45, pp. 1331–1358; October, 1957.

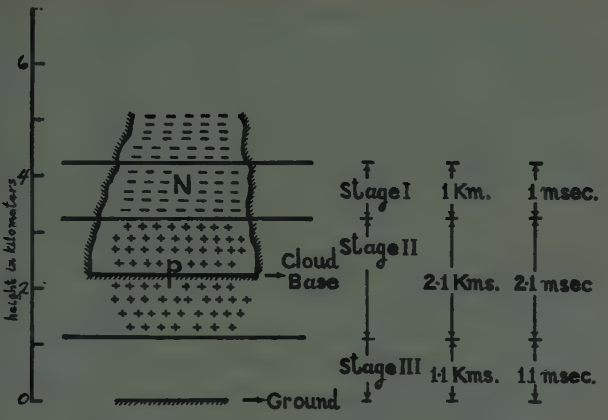


Fig. 2—First leader to ground and its stages.

0.0021 second. The "pocket" created by a step in this stage does not cut out any radiation in the medium and short wavebands (see Appendix). As it occurs at a lower height, δ is probably lower in value.

Stage III

This occurs from the end of the positive region to ground, and probably corresponds to what is often called alpha leader in lightning discharge literature. Steps are formed in charge-free air at definitely lower heights from ground and near ground. Steps are short and the intervals between steps are shorter. Because of the charge-free nature of air and the lower altitude, δ is distinctly of lower value and it appears that X for this region is about 1/10 of its value for stage I or stage II. The lower values of X and the step length considerably reduce the amplitude of radiation so that the radiation from this region becomes negligible compared to that from stage II for the medium waveband.

In the second and subsequent leaders to ground, stage III is generally absent; *i.e.*, there is no stepped nature for this length of the leader path. Similarly, the greater portion of stage II is not stepped. That is, for practical purposes, the few indeterminate steps if they occur at all in stage II of second and subsequent leaders, can be neglected in calculations. But stage I is always stepped in all the four leaders to ground.

When the height of the cloud base above ground is between 2.2 and 4 km, there is the possibility of stage I and part or all of stage II for the first leader, and stage I and a negligible part of stage II for the second and subsequent leaders. Each leader is followed by a process similar to recoil described earlier. All these correspond to what is generally called an air discharge. When the height of the cloud base is less than 2.2 km from ground, part or all of stage II may disappear.

MEDIUM WAVE NOISE RADIATOR

From the discussion in the preceding sections, it is clear that the electrical processes accompanying cloud discharges do not contribute noise in the medium waveband. The author's observations in Poona and Ahmedabad show that discharges within the cloud constitute 90 per cent of all discharges. Cloud-to-ground discharges and cloud-to-air discharges together appear to constitute the remaining 10 per cent, of which the majority are cloud-to-ground strokes. These facts appear to hold for the tropics and, it follows, therefore, that only 10 per cent of the tropical thunderstorm discharges can contribute noise in the medium waveband.

In the cloud-to-ground or cloud-to-air discharges, it is only stage II of the stepped leader that can radiate noise in the medium frequency band. Stage II exists for the first leader of all cloud-to-ground strokes and, to a great extent, for cloud-to-air discharges. Part of stage II may exist for the second and subsequent leaders. Therefore, stage II of the first leader to ground or into the air is the principal source of noise in the medium waveband. There may be a small effect of part of stage II that may appear in the second and subsequent leaders, but it is not necessary to take account of this in calculations. This stage II differs from stage I in the following three characteristics only: 1) It is of longer duration, *viz.* 0.0021 second. 2) The "pocket" associated with a step does not cut out radiation in the medium and short wavebands. 3) The value of δ is lower.

About half of stage II is in the cloud and the other half is outside the cloud. Assuming that the value of δ at 2.1 km from ground corresponds to the average value for the whole of stage II, and using the conductivity value for air at an altitude of 2.1 km as given by Gunn,[9] δ can be calculated from (3). This procedure is reasonably correct as we are below the cloud base at 2.1 km altitude. The value of δ so obtained is 4.6×10^6 sec^{-1}.

The data required for a discussion of atmospheric noise in the medium waveband are reproduced in Table II. We are now in a position to summarize how noise in the medium waveband arises. A thunderstorm in which a discharge occurs in the air or to ground radiates at least 10 flashes[10] per minute during peak

TABLE II

DATA FOR TYPICAL CLOUD-TO-GROUND OR AIR DISCHARGES

T_f = over-all duration of a flash = 0.2 second
N = minimum number of flashes per minute during peak activity = 10
n = number of strokes per flash = 4
= number of leaders
n_1 = number of leaders having the entire stage II = 1
T_s = time interval between strokes in a flash = 0.04 second
T_L = over-all duration of stage II of the first stepped leader = 0.0021 second
T = time duration of a step = less than a microsecond
T_i = time interval between steps = 0.000074 second
ν = recurrence frequency of the steps = 13500 cps
l = length of a step in a stepped leader = 67 meters
δ = constant in the expression for the exponential rise of current in the discharge in a step in stage II of the leader = 4.6×10^6 sec^{-1}.
X = maximum rate of change of current in a step = 10^{10} amperes per second

---

[10] All the flashes need not necessarily strike the ground.

activity. A typical flash consists of four strokes and it is only stage II of stepped leaders that radiates noise in the medium frequency band. Hence, stage II of the first leader radiates a train of impulses for 0.0021 second. Each impulse lasts a fraction of a microsecond and the time interval between the impulses is 0.000074 second. This may be followed at intervals of 0.04 second by the radiation of a few similar impulses thrice. The Fourier components of all these impulses travel through space like other radio waves and those lying within a bandwidth, B, at a frequency, f, are picked up by the receiver and produce the acoustic impulse heard by the ear. The characteristics of this interfering acoustic impulse are examined in the next section.

The Interfering Acoustic Impulse

It has already been pointed out that the maximum value of the amplitude of sound averaged over 0.001 second gives a proper measure of the apparent loudness of an impulse as assessed by the ear.[1] As per discussion in the previous section, stage II of the first stepped leader in the discharges to ground or into the air radiates a train of impulses for 0.0021 second. It is difficult to evaluate the maximum average amplitude for 0.001 second during this period of 0.0021 second. Further, it appears that this value will not differ significantly from the average value for 0.0021 second. Hence, the latter will be taken as a proper measure of the apparent loudness of the impulse as assessed by the ear. That is, we will regard the average amplitude arising from a train of impulses lasting 0.0021 second, as the quantity we are interested in and hence confine our discussion to the equivalent rectangular pulse lasting 0.0021 second.

Such a rectangular pulse can be regarded as roughly corresponding to half of a complete 100 per cent modulated envelope. It follows that the equivalent modulating frequencies probably correspond to 238 cps; *i.e.*, roughly 240 cps, and their harmonics. The corresponding modulating frequencies evaluated for short-wave broadcasting were 500 cps and their harmonics. The predominant frequency in the noise impulse is lower for the medium waveband than for the short waveband. This fact is fully consistent with the author's observations during the last decade that the noise impulse as heard in the medium waveband has a lower AF than the one in the short waveband.

Since the predominant AF corresponds to 240 cps, this frequency should be used as the modulating frequency in the standard signal generator used for calibrating the noise meter. As there is no essential difference between 240 and 400 cps either theoretically or from the practical standpoint, the use of 400 cps as the modulating frequency appears to be a scientifically justifiable step.

A time plot of the actual radiation from a flash that gives rise to noise in the medium waveband and the corresponding acoustic impulses are given in Fig. 3. There is a full train of impulses from the first leader. From the second, third, and fourth leaders, there *may* be radiation of a few impulses but this will always be indeterminate. The duration of such trains, however, will be for less than 0.001 second and as the average value for such trains has to be deduced for 0.001 second, it will obviously be very small. There being no certainty of radiation from leaders subsequent to the first, the impulses radiated and the equivalent acoustic impulses arising therefrom are shown in Fig. 3 by use of dotted lines.

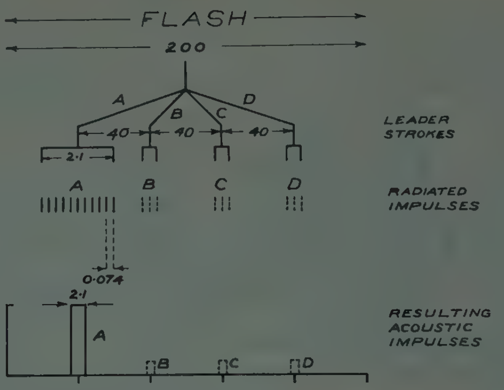


Fig. 3—Acoustic impulses from stage II of cloud to ground leaders. (Time intervals shown in milliseconds.)

From Fig. 3, it is obvious that the trains of impulses are *equivalent* to rectangular pulses and that they produce such rectangular pulses after rectification. The pulse at A is of the highest magnitude and longest duration but the pulses at B, C, and D, if they occur at all, are only of 0.001 second duration and of very small amplitude. The integrated effect of the pulses at A, B, C, and D over a period of 0.2 second is what produces the effect equivalent to continuous sound on the ear and the calculation has to be carried out by taking note of the charging and discharging time constants of the noise meter. The pulse at A produces the effect at A and its amplitude gradually decays. The effect of the small pulses at B, C, and D is to superpose the decay curves of their amplitudes on that of the pulse at A. Therefore, the actual acoustic impulse as heard by the ear becomes ill-defined and gives the impression of being rather drawn out. If, at any time during 0.2 second, the net effect of the pulses at B, C, and D increases the amplitude of the pulse at A by 3 db or more for 0.001 second, this effect will be noticed by the ear and can be regarded as a hump in the decay curve of the amplitude of the pulse produced at A. Experimental observations of the acoustic noise pulse as heard by the ear and also as measured by the meter, indicate that this does occur. Therefore, the maximum effect on the ear may be at A or at any point between A and D. Further, observations indicate that this increases the amplitude corresponding to that at A by 3 to 6 db, 3 db being the more common. However, this hump producing effect is not "typical."

From the discussion in the previous paragraph, the following conclusions can be drawn. For practical purposes, it is best to discuss the problem by considering the pulse at A only and ignoring the effects of the pulses at B, C, and D. But, in considering the higher decile values of the noise levels, an allowance of 3 db may be made for the possible hump producing effect of the pulses at B, C, and D. On the basis of this simplified approach, we now proceed to deduce the equivalent amplitude of the corresponding continuous wave carrier, its level of the modulation, etc., in exactly the same manner as before.[1]

Suppose the carrier amplitude corresponding to a rectangular pulse like the one at A in Fig. 3 is Y. Then, taking account of the efficiency of rectification of modulation, 0.9, the duration of the pulse, 0.0021 second, and the charging time constant of the noise meter, 0.01 second, the amplitude of the equivalent continuous wave carrier, Z, is given by

$$Z = (0.9)\cdot(0.0021/0.010)\cdot Y = (0.189)\cdot Y \tag{5}$$

$$\fallingdotseq (0.19)\cdot Y. \tag{6}$$

A point worth noting here is the fact that the discharging time constant, 0.5 second, does not come into the calculation as we are dealing with one pulse only.

As before,[1] it follows that the noise impulse produces an effect on the ear that corresponds to a depth of modulation of 0.19 of this equivalent continuous wave carrier. The depth of modulation chosen for the noise meter calibration is 0.3. Hence, in comparing measured noise levels with estimates, it is necessary to reduce either of the two by use of (1). In evaluating standards of satisfactory service in the medium waveband, due account must be taken of the fact that the depth of the equivalent modulation of the noise impulse is 0.19 and *not* 0.30 as in the case of the short waveband.

POWER RADIATED BY A FLASH

The discussion of the previous sections makes it clear that a flash to ground or into the air radiates principally one train of impulses which gives rise to noise in the medium waveband. These impulses occur at random and the recurrence frequency is ν (see Table II). The bandwidth of the receiver, B, is 6000 cps. For such a case, the root mean square amplitude arising from the train of impulses has been calculated.[3] In this calculation, it has been assumed that δ is much less than ω_0 and δ is neglected. If this assumption is removed, we get the following expression:

$S(\omega_0)$ = root mean square amplitude due to a stroke in a flash

$$= \sqrt{2\nu B}\cdot\frac{X\cdot l}{\sqrt{\omega_0^2+\delta^2}} \tag{7}$$

where,

$$\omega_0 = 2\pi f \tag{8}$$

and f is the frequency to which the receiver is tuned.

The train of impulses arises from stage II of the first leader to ground or into the air and each impulse is radiated by a step. Since all these steps are in stage II of the leader, they can be considered to be high above ground. They are of short length and practically vertical. Therefore, the radiator can be regarded as a short vertical dipole in free space. Taking account of these facts and the gain factor of the antenna, the following expression has been deduced[3] for the peak electric field intensity due to a stroke in a flash in $\mu V/m$:

$$E_1 = \frac{30}{cr}\cdot S(\omega_0)\sqrt{(1.5)}\sin^2\theta \tag{9}$$

where

c = velocity of light in meters per second,
r = distance of the point from the source in 10^6 meters,
θ = angle the direction of radiation makes with the axis of the dipole.

As before,[1] the average value of the electric field due to a train of impulses is given by

$$E_2 = (0.85)\cdot E_1. \tag{10}$$

E_2 corresponds to Y in (6) but we require E which corresponds to Z in the same equation and, hence,

$$E = (0.85)\cdot(0.19)\cdot E_1. \tag{11}$$

In noise estimations, we calculate the field, E, in $\mu V/m$ at a point distant, r, from the source from the following expression:

$$E = 212\cdot\sqrt{P/1000}\,\frac{\sin\theta}{r} \tag{12}$$

where

P = statistical median value of the equivalent power radiated by the noise source in watts.

From (7), (9), (11), and (12), the value of P can be deduced and after substituting the numerical values for the quantities involved from Tables I and II, we get

$$P = \frac{16.1}{f^2}\cdot\frac{1}{1+\dfrac{\delta^2}{4\pi^2 f^2\cdot 10^{12}}} \tag{13}$$

$$= \frac{16.1}{f^2+\dfrac{\delta^2}{4\pi^2\cdot 10^{12}}} \tag{14}$$

where

f = frequency in mc,
$\delta = 4.6\times 10^6$ sec^{-1}.

In (14), δ can be neglected when

$$\frac{\delta^2}{4\pi^2\cdot 10^{12}} < \frac{1}{10}\cdot f^2, \tag{15}$$

i.e., when

$$f > 2.3 \text{ mc.} \tag{16}$$

Similarly, in (14), f can be neglected when

$$f^2 < \frac{1}{10} \cdot \frac{\delta^2}{4\pi^2 \cdot 10^{12}}, \tag{17}$$

i.e., when

$$f < 0.23 \text{ mc.} \tag{18}$$

Below 0.23 mc, the power radiated is practically independent of f and has a constant value of 30 watts. This question will not be discussed here as the problem of noise radiation below 0.23 mc is the subject matter of a separate communication.

From (18), it follows that (13) holds for all frequencies above 0.23 mc. But, beyond 2.5 mc, the radiation from discharges within the cloud becomes much more important and since such discharges are much more frequent, (13) is of no significance. It is, therefore, concluded that (13) holds from 0.23 to 2.5 mc.

It is necessary to emphasize that the frequency limits for the validity of (13), *viz.*, 0.23 and 2.5 mc, should not be taken too rigidly. The lower limit depends on δ, which is estimated from conductivity measurements. The higher limit has been evaluated in the Appendix. The limits have been evaluated with some care and have the support from the author's preliminary noise measurements, but detailed investigations may lead to a slight revision of these values.

A preliminary report of the sequence of experimental work which led to the calculations reported in this paper and the actual equation as given in (13) has already been made.[11] A detailed report of the actual experimental work and its comparison with the estimates deduced from (13) will shortly be published elsewhere.[12]

CONCLUSION

This paper gives a brief summary of the physical picture of a typical tropical thundercloud and some of the electrical discharges, etc., associated with it. This has been deduced from lightning discharge data. It will be seen that the first stepped leader to ground has four parts roughly of the same length, *viz.*, 1 km. Two of these parts together constitute stage II as defined. Both these parts occur in the lower positive region, but, one part is within the cloud and the other outside the cloud. Photographic methods may often get only this lower part of stage II. Similarly, only the upper part of stage II may be regarded as a cloud discharge. The possibility of confusion is increased by the fact that stage I and the whole of stage II have the same values for the length of the stepped leader, interval between steps, etc. Detailed discussions are undertaken elsewhere[7] but it is sufficient to state here that this typical tropical thundercloud as described appears to represent facts in their essentials. Since the paper is restricted in scope to a discussion of "typical" cases, uncommon cases have been entirely eliminated.

The concept of the interfering acoustic impulse and the calculation of the equivalent power radiated by the source have been discussed in detail earlier[1] and a review of these becomes unnecessary here.

It has been stated that cloud discharges do not radiate any significant power below 2.5 mc. The author carried out some preliminary experiments by changing the tuning and listening to the noise impulse when only cloud discharges were taking place and found an abrupt change of noise magnitude in the region, 2 to 3 mc. When local thunderstorms were followed by noise measurements simultaneously at a number of frequencies, the result was confirmed. An explanation for this has been attempted in the Appendix.

The statement that cloud-to-ground strokes are the principal sources of noise in the medium waveband is based on actual observations but the statement that cloud-to-air discharges also give rise to noise in this band is based on inference.

Systematic noise measurements were carried out for a complete year, 1954–1955, in the standard broadcast band and repeated again in 1955–1956. The two sets of data were carefully examined to confirm consistency and every possible care was taken in carrying out measurements in 1955–1956. The noise levels, deduced on the basis of such measurements, can only be explained, and explained satisfactorily, on the basis of deductions in this paper. The estimates agree well with measured values. This is perhaps the most striking indication that the approach to the problem as given in this paper is probably in the right direction.

APPENDIX

POCKETS IN ACTIVE THUNDERCLOUDS

Experimental results indicate that cloud discharges do not radiate noise below a certain frequency and that this frequency lies between 2 and 3 mc. An attempt is made here to explain these results and calculate the actual cutoff frequency.

Cloud Characteristics for Step Formation

A typical tropical thundercloud is shown in Fig. 1. It has certain electrical characteristics. These change when the thundercloud becomes active and lightning discharge commences. An active thunderstorm thus can be regarded to exist under disturbed conditions. Conditions that exist in a thundercloud prior to its becoming active can be called normal conditions. For understanding the changes that take place with the commencement of activity of a thunderstorm, we require the electrical characteristics of a thundercloud under normal conditions. The closest approach to such conditions is probably a mild cold front with no lightning activity. Data for such a case are given in Table III of Gunn's paper.[9] This table can be used for a tropical thundercloud provided we abstract from it data corresponding to the same isotherm.

We now consider the mechanism of a cloud discharge. Physical processes occur leading to the development of intense electric fields. This is followed by the initiation of the flash. The first leader stroke appears to always commence approximately at the freezing level or zero degree isotherm. Subsequent strokes commence from higher regions. The first step in the first leader stroke occurs on the zero degree isotherm. Subsequent steps occur at lower levels but under disturbed conditions. Similarly, steps of subsequent leader strokes occur at other levels but again under disturbed conditions. Therefore, it is reasonable to assume that typical conditions existing in the cloud prior to the formation of a step are those corresponding to the first step of the first leader stroke. On this basis, the data in Table III of Gunn's paper corresponding to 0°C represent the normal electrical characteristics of a tropical thundercloud prior to the appearance of a step. The relevant information is reproduced in Table III.

---

[11] S. V. C. Aiya, "Noise radiation from tropical thunderstorms in the standard broadcast band," *Nature*, vol. 178, p. 1249; December, 1956.

[12] S. V. C. Aiya and C. G. Khot, "Atmospheric noise interference in the standard broadcast band at Poona," (to be published).

TABLE III

Cloud Characteristics for Step Formation

1) Temperature = 0°C
2) Charge on a positive drop = +0.042 esu
3) Charge on a negative drop = −0.100 esu
4) Positive particle space-charge density = 1.0×10^{-5} esu/cm^3
5) Negative particle space-charge density = -4.6×10^{-5} esu/cm^3
6) Excess negative particle space-charge density = -3.6×10^{-5} esu/cm^3

Pocket Formation

The zero degree isotherm will be across the N region of Fig. 1. This region contains electrons, ions, and charged drops. The drops are so heavily charged that, in any approximate calculations involving charges, we can neglect the electrons and ions. Consider the negatively charged drop. As in Table III, it has a negative charge of 0.1 esu, *i.e.*, a considerable number of electrons are attached to it. It is well known that, under the action of intense electric fields, such electrons attached to the drop can get separated from it. The free electrons so produced go to form an electron gas.

An intense electric field exceeding the disruptive strength of the dielectric initiates the discharge and the appearance of steps. We are not interested here in the actual step formation but in the phenomena accompanying it. The effect of the intense field is felt not only in the portion of the cloud where the step appears but also in the space immediately surrounding it. We describe this space immediately surrounding the step as a pocket. In this pocket, electrons are liberated from the negatively charged drops by the action of the intense electric field. The pocket thus gets filled with an electron gas. The physical condition of this pocket is thus different from the conditions prevailing in the N region of the cloud elsewhere. (Such pockets account for the observed reflections from active thunderclouds in radar studies of cloud behavior.)

The creation of the pocket precedes the appearance of the step as it commences with the production of electric fields of much lower value. This pocket, once created, gradually disappears and traces of it exist practically until the commencement of the next stroke. During pocket formation, positive and negative charges get neutralized and the excess negative space-charge density appears in the form of an electron gas. Therefore, the electron density in the pocket is given by

$$n = \frac{3.6 \times 10^{-5}}{4.77 \times 10^{-10}} \tag{19}$$

$$= 7.548 \times 10^4 \text{ electrons/cc} \tag{20}$$

(4.77×10^{-10} is the electronic charge in esu).

Wave Propagation through the Pocket

It follows from the previous section that the pocket is equivalent to a medium containing free electrons. Propagation of electromagnetic waves through such media is well known. The refractive index of such media is given by

$$\mu = \sqrt{1 - \frac{81\cdot n}{f^2\cdot 10^6}} \tag{21}$$

where

$$f = \text{frequency in mc.} \tag{22}$$

The refractive index depends on the frequency of the wave and the electron density in the medium. There is propagation of waves when when the refractive index is real. When the refractive index is imaginary, attenuation takes place and the pocket will not transmit the waves; this happens when

$$f < \sqrt{\frac{81\cdot n}{10^6}}, \tag{23}$$

i.e.,

$$f < 2.47 \text{ mc}, \tag{24}$$

i.e.,

$$f < 2.5 \text{ mc approximately.} \tag{25}$$

This shows that the pocket behaves in a manner similar to a waveguide and cuts out radiations from the step of the leader for all frequencies below 2.5 mc.

General

The behavior of the pocket as explained in this note is applicable to the N region of the cloud where there are excess negatively charged drops and electron gas formation is possible. Cloud discharges occur in the N region and hence, the discussion holds for cloud discharges. In the p region of the cloud or below it, there is excess of positively charged drops and, therefore, there are no possibilities for the electron gas formation in the pocket and the discussion of this note does not apply. If the pocket is full of charged ions, the cutoff frequency will be very much lower as it depends on the mass of the ions and the ion density. Hence there is no waveguide action for radiations from stage II in Fig. 2 for the frequencies in the medium and short wavebands.

A detailed discussion of the problems examined here will be found elsewhere.[7]

Suppression of Undesired Radiation of Directional HF Antennas and Associated Feed Lines*

H. BRUECKMANN†, FELLOW, IRE

Summary—An analysis of the situation in point-to-point radio communication circuits at frequencies below MUF with respect to radiation in undesired directions brings to the fore some aspects which are useful as guide lines in antenna research, design, and application engineering.

In many cases, the interference experienced in operating receivers in the high-frequency range can be attributed primarily to the relatively high side lobes of the radiation pattern of rhombic antennas. Progress has been made in suppressing these side lobes through the development of antenna arrays employing nonuniform amplitude distributions and, more recently, through the advent of modified horn-type antennas. Other sources of interference which are usually overlooked are associated with balanced open-wire lines which are not operated properly. Recently, it has become feasible to replace these lines by coaxial cable using broad-band balun transformers.

INTRODUCTION

THIS discussion is concerned with only one category of applications of HF antennas, though it is one of great importance: long-range fixed-point-to-point radio communication at frequencies below MUF. It is exemplified in the Army Global Communication System of strategic circuits operated by the Army Communications and Administrative Network (ACAN), mostly at frequencies between 5 and 25 mc. Ionospheric scatter propagation, mobile stations, or short-range circuits are not discussed, although some of the considerations here apply equally well. We are faced here with applications in which the usable signals carrying the desired information depart from the transmitting antenna and arrive at the receiving antenna in a relatively narrow solid angle (between about 5 and 15 degrees elevation angle, depending on the range, layer height, number of hops, etc., and between ± about 5 degrees azimuth angle relative to the azimuth of the Great Circle through receiver and transmitter). The deviations from the Great Circle path depend on the range, irregularities of the ionospheric layers, etc. Other paths for the desired signal outside this solid angle may exist, but they are not usable or dependable and may be even harmful. Capability of the receiving antenna to receive from other directions makes the radio circuit only more susceptible to interference. There is an analogy between spurious frequency responses, or generations of electronic equipment, and spurious side lobes of directional antennas. Frequency allocation corresponds here to geographical location. A typical situation at a receiving station is depicted in Fig. 1(a) for the horizontal plane. Actually, the problem is a three-dimensional one. For the sake of simplicity the third dimension is omitted in Fig. 1(a), but has to be taken into account in a thorough investigation, as illustrated in Fig. 1(b). For subsequent considerations, it is useful to introduce a number of short terms which permit describing quantitatively either a particular application or a particular antenna.

GENERAL CONSIDERATIONS

In general, the bearing of the direction of arrival of the usable signal varies with time. The variations are statistical. The sector which encompasses all variations in the bearing of the direction of arrival of the useful signal with time for a specified percentage of the total circuit time shall be called "sector of arrival of the desired signal." For a typical circuit, it is less than 10 degrees for 80 per cent of the total circuit time. This sector, in general, is not symmetrical about the direction of the Great Circle through transmitter and receiver due to the propagational effects of the auroral zone.

In many cases, the likely source of strong interfering signals is known, or at least the place is known where no strong interference is to be expected. The sector (or sectors) which covers all bearings from which strongly interfering signals (usually a multiplicity of them) arrive, or are likely to arrive, may be called "critical sector." It is also a value of a statistical nature, rather than a constant, and has to be handled accordingly. For many reasons, advantage should be taken of the knowledge of the geographical situation, if at all possible.

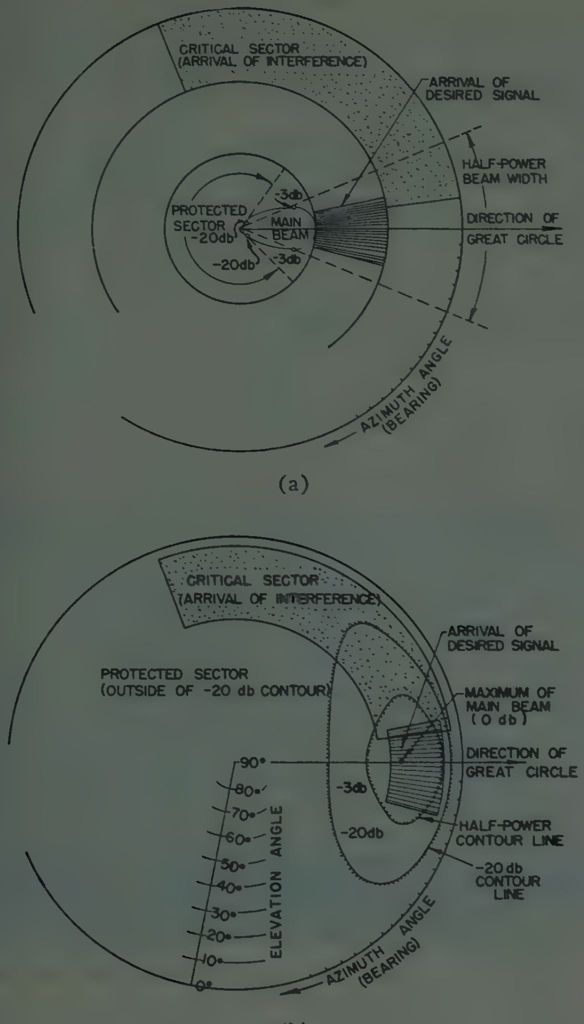
The designation of "horizontal half-power beamwidth" for the azimuthal angle between the extreme bearings of the half-power points of the main beam has been generally accepted. It is a property of the particular antenna used. The two terms discussed below are also properties of the antenna.

The capability of a given antenna to reject interference can be expressed by the ratio of the gain in a specified direction, as seen from the antenna, to the gain in the direction from which the desired signal arrives. It shall be called "rejection ratio." This term is an abstraction which purposely disregards the existence of the ionosphere. It is identical with the radiation pattern only if the desired signal arrives in the direction of the maximum of the main beam.

---

* Manuscript received by the IRE, November 28, 1957. This paper was presented at the Symposium on Electromagnetic Interference, Asbury Park, N. J., November 20, 1957.

† U. S. Army Signal Res. and Dev., Fort Monmouth, N. J.


CRITICAL SECTOR (ARRIVAL OF INTERFERENCE)
ARRIVAL OF DESIRED SIGNAL
HALF-POWER BEAM WIDTH
PROTECTED SECTOR -20db
-3db
MAIN BEAM
-20db
-3db
DIRECTION OF GREAT CIRCLE
AZIMUTH ANGLE (BEARING)
CRITICAL SECTOR (ARRIVAL OF INTERFERENCE)
ARRIVAL OF DESIRED SIGNAL
PROTECTED SECTOR (OUTSIDE OF -20 db CONTOUR)
MAXIMUM OF MAIN BEAM (0 db)
DIRECTION OF GREAT CIRCLE
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
ELEVATION ANGLE
-3db
-20db
HALF-POWER CONTOUR LINE
-20 db CONTOUR LINE
AZIMUTH ANGLE (BEARING)

(a)

(b)

Fig. 1—(a) Plan view presentation of various sectors involved in the operation of typical radio communication receiving antenna affected by interference (schematic). Inner circle shows the antenna pattern, middle ring the desired signal, and the outer ring shows the interference. (b) Contour-map presentation of the same situation as the one depicted in (a).

The sector or sectors within which the radiation of a given antenna is a specified ratio (for example −20 db), or less than the radiation in the maximum of the main beam, shall be called the "protected sector." In other words, within this sector the rejection is higher than a specified minimum.

With this nomenclature, it is possible to make some general statements on receiving antennas. They are useful as guide lines for research and development as well as application engineering.

The protected sector is always smaller than 360 degrees minus the half-power beamwidth, because the beamwidth between directions for which the gain is lower than −3 db is larger. The factor by which it is larger corresponds to the so-called "form factor" of receiver-selectivity characteristics and does not greatly depend upon whether, say, 20 or 30-db rejection ratio is specified. Provided the side lobes are lower than is necessary to meet the required minimum-rejection ratio, the protected sector is always about 360 minus 3 times the half-power beamwidth. In other words, decreasing the half-power beamwidth by a certain amount increases the protected sector by 3 times that amount and vice versa, if only the side lobes can be kept low enough.

If the critical sector of interference overlaps completely with the sector of arrival of the desired signal, little can be gained by using low-side-lobe antennas, assuming that the interference is stronger than thermal and static noise. Of course, a simple antenna will then perform operationally almost as well as an elaborate one. If, however, the critical sector overlaps only partially with the sector of arrival of the desired signal, the rejection ratio can be improved by slewing the main beam by an angle equal up to about half of the half-power beamwidth in the proper sense.

Since an antenna approaching the ideal is always difficult and costly to build, a possible compromise is an antenna which has a high rejection ratio for signals arriving from directions within the critical sector, at the sacrifice, if necessary, of a low rejection ratio for directions outside this sector. This approach has not yet been given much attention, but has the potentiality of leading to simple and relatively inexpensive solutions. Such a statement will become clearer when recent approaches aiming at the ideal antenna are considered.

If we consider transmitting antennas now, we can see that the above terms and conclusions about receiving antennas apply equally well, after substituting "depart" for "arrive." The protection relates then to other circuits, rather than to the circuit under consideration. Yet the suppression of undesired radiation from transmitting antennas has been given, in the past, much less importance than that from receiving antennas. The reasons for this are obvious and are not discussed here. It is believed, however, that sooner or later a stage of development will be reached at which both are given equal importance.

RECEIVING ANTENNAS

Efforts, reported below, to improve receiving antennas had to start from the state of the art established by the rhombic antenna which has been dominating the appearance of overseas radio stations for the last 30 years. For some years, the rhombic has become more widely recognized as the compromise solution which it is with respect to frequency range and directivity. Extensive measurements[1] of the radiation patterns of an operational typical rhombic antenna 756 feet long and 260 feet wide have provided precise information on the magnitude of the side lobes. The chart of Fig. 2 gives their direction and magnitude relative to the main lobe at four frequencies. This chart lists the horizontally polarized side lobes up to elevation angles of about 30 degrees only. Although the other polarization and higher elevation angles are not included, the chart gives a fairly complete picture of the performance of rhombics. It shows that: 1) azimuthal direction of all side lobes at all frequencies measured agrees excellently with theory whereas agreement of calculated and measured elevation angles of side lobe maxima may be called reasonable; 2) magnitude of the side-lobe maxima in the front sector, as far as determined, agrees fairly well with theory; and 3) agreement of the magnitude of the side-lobe maxima in the rear sector with theory is poor. (This is plausible in view of the fact that small reflections at the termination and the side poles are bound to affect the pattern in the rear section profoundly.)

---

[1] H. Brueckmann, "Analysis of Measured Radiation Patterns of Two HF Antenna Arrays and One Rhombic," U. S. Army Signal Engineering Labs., Rep. E-1198; January, 1957.

The measurements have again demonstrated that rhombics poorly reject interfering signals arriving from the forward sector over the entire frequency range. At all frequencies, some side lobes exist which are only about 6 to 10 db down from the main lobe. The back lobe varies between −6 and −20 db, decreasing gradually in strength with increasing frequency, as do the other side lobes in the rear sector.

About four years ago, a reappraisal of the situation with respect to interference in strategically important circuits of the Army, led to the conclusion that some of these circuits had to be equipped with low-side-lobe receiving antennas immediately. However, the state of the art at that time did not permit reducing side lobes and at the same time satisfying the frequency range requirements. In order to break the deadlock, the concept of covering the required minimum frequency range from 6 to 18 mc with one antenna was abandoned. Two different prototype antennas were built under this program, for which the design information[2] was supplied by this laboratory. Both were designed for a narrow band, one centered around a frequency below 10 mc., and the other one centered around a frequency above 10 mc. Fig. 3 shows an over-all view of the antenna for lower frequencies which was built by Developmental Engineering Corporation under Signal Corps contracts.[3,4] It consists of a vertical plane wire-grid acting as a parasitic reflector, seven wavelengths or over-all 950 feet wide, and 3/4 wavelength or 104 feet high, with 12 vertical elements in front of it. Fig. 4 shows the antenna for higher frequencies which was built by a Signal Corps construction company under the direction of the U.S. Army Signal Communication Engineering Agency. It consists of two vertical curtains of 12 horizontal full-wave dipoles each of which is fed. The over-all width of this array is also seven wavelengths or about 560 feet, its height is 1½ wavelengths or 123 feet. In both arrays

	FREQ 4.932 MC MAIN LOBE MAX POWER GAIN* 10.9db			FREQ 7.465 MC MAIN LOBE MAX POWER GAIN* 19.2db			FREQ 12.2525 MC MAIN LOBE MAX POWER GAIN* 23.8db			FREQ 17.465 MC MAIN LOBE MAX POWER GAIN* 25.3db		
LOBE NO.	AZIMUTH DEG.	ELEVA. DEG.	AMPLI. db	AZIMUTH DEG.	ELEVA. DEG.	AMPLI. db	AZIMUTH DEG.	ELEVA. DEG.	AMPLI. db	AZIMUTH DEG.	ELEVA. DEG.	AMPLI. db
1	31	15.5	-13.1	42	10	-5.5	19	9.2	-19.2	15	8.5	-11.4
2	55	27	-7.0	59	5.7	-14.8	29	9.2	-11.5	32	5.8	-9.6
3	88	27	-13.0	79	10	-14.5	42	9.2	-7.5	41	8.5	-10.8
4	123	21.6	-16.5	180	30	-13.6	65	9.2	-17.7	50	8.5	-13.2
5	180	27	-5.9				78	9.2	-17.5	59	8.5	-18.0
6							177	9.2	-22.8	66	8.5	-18.8
7										76	8.5	-18.5
8										180	8.5	-19.3

* Main lobe maximum power gain figure is relative to isotropic radiator.

Fig. 2—Orientation and magnitude relative to main lobe of measured horizontally polarized side lobes of RD-4 rhombic at four frequencies.

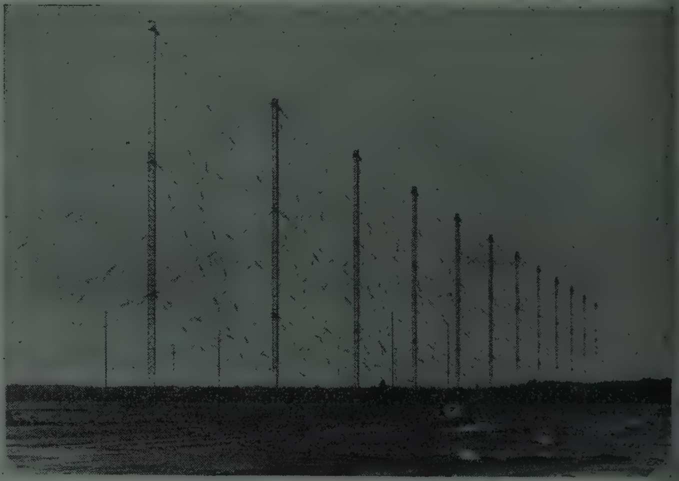


Fig. 3—Vertical antenna array employing nonuniform amplitude distribution.

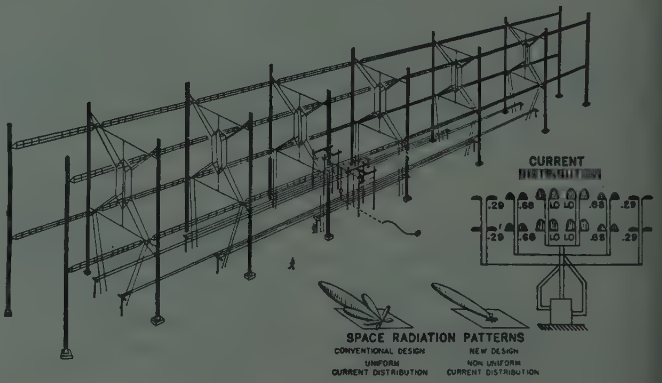


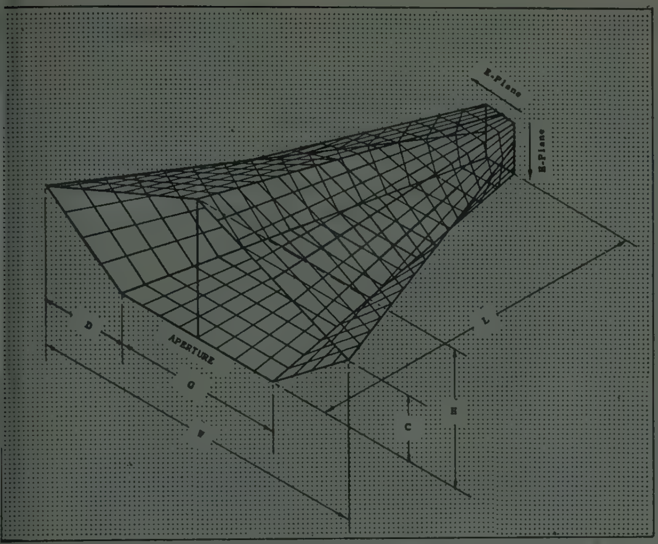
Fig. 4—Arrangement of supports of final category A1 antenna.

---

[2] H. Brueckmann, "HF Broadside Antenna Arrays with Non-Uniform Amplitude Distribution," U. S. Army Signal Engineering Labs., Rep. E-1214; September, 1957.

[3] D. F. Bowman, "Broadside Antenna Array of 12 Vertical Elements with Non-Uniform Current Distribution," Developmental Engineering Corp., Leesburg, Va., Signal Corps Contract DA-36-039 SC-56762, Final Tech. Rep.; September, 1954.

[4] H. A. Ray and B. G. Hagaman, "HF Vertically Polarized Directional Antenna Array," Developmental Engineering Corp., Leesburg, Va., Signal Corps Contract DA-36-039 SC-64670, Interim Tech. Rep.; December, 1955.



	L	W	H	C	D	G
FULL RANGE TAHA AT 7 Mc.	844' 6λ	506' 3.6λ	253' 1.8λ	85' 0.6λ	169' 1.2λ	169' 1.2λ
LOW-RANGE TAHA AT 5 Mc.	795' 4.1λ	795' 4.1λ	398' 2λ	199' 1λ	265' 1.3λ	265' 1.3λ
HIGH-RANGE TAHA AT 12 Mc.	334' 4.1λ	334' 4.1λ	167' 2λ	84' 1λ	110' 1.3λ	110' 1.3λ

Fig. 5—Characteristic dimensions of TAHA.

the amplitude distribution of the excitation of the dipoles with respect to each other is nonuniform in contrast to conventional arrays. The particular taper employed is the so-called Dolph-Tchebycheff distribution. It is believed that these arrays are the first ones in the high-frequency range and in the field of radio communication which employ nonuniform amplitude distribution. The half-power beamwidth of both arrays is 10 degrees, the gain 24 db. The side lobes of the vertical array were measured to be 23 db, or more, down from the main lobe. The horizontal array was in faulty condition during the last measurements, which was discovered only afterward. The measured side-lobe level of −20 db is not representative, therefore. All indications are that eventually a side-lobe level of −26 db, or less, can be achieved. In summarizing, it can be said that these arrays reduce the side lobes, compared to a rhombic of comparable gain, by about 20 db, a spectacular improvement from the interference-suppression point of view. But this improvement is bought at the expense of the width of the frequency range of a single antenna and necessitates a separate antenna for each operating frequency, not to speak of the increase in cost, complexity, and required real estate.

Faced with this serious shortcoming of arrays and stimulated by the experience gained in designing them, a new approach to the problem of the broad-band directional antenna with low side lobes was taken at the beginning of 1956. This approach was along the line of horn-type antennas. It culminated in the design of TAHA (Tapered Aperture Horn Antenna) by Boynton G. Hagaman, Developmental Engineering Corporation, Leesburg, Va., under contract with these laboratories.[5] Fig. 5 gives an idea of its configuration. Construction of a full-scale prototype is at present under way. Its overall dimensions are: length 850 feet, height 250 feet, width 560 feet. The performance data determined so far by model measurements are impressive. Side-lobe level is −20 db, or less, over the entire frequency range. Fig. 6 shows that the horizontal beamwidth of TAHA can be made to equal that of a rhombic over the entire frequency range of the latter.

It is believed that, at long last, a substitute for the rhombic antenna has been found which is, for a given gain or beamwidth, equal if not better with respect to bandwidth and, at the same time, much superior with respect to side-lobe suppression by a factor in the order of 15 to 20 db. No doubt, this technical advance has to be paid for. The development which is still in progress has not gone far enough, however, to permit a fair comparison of costs.

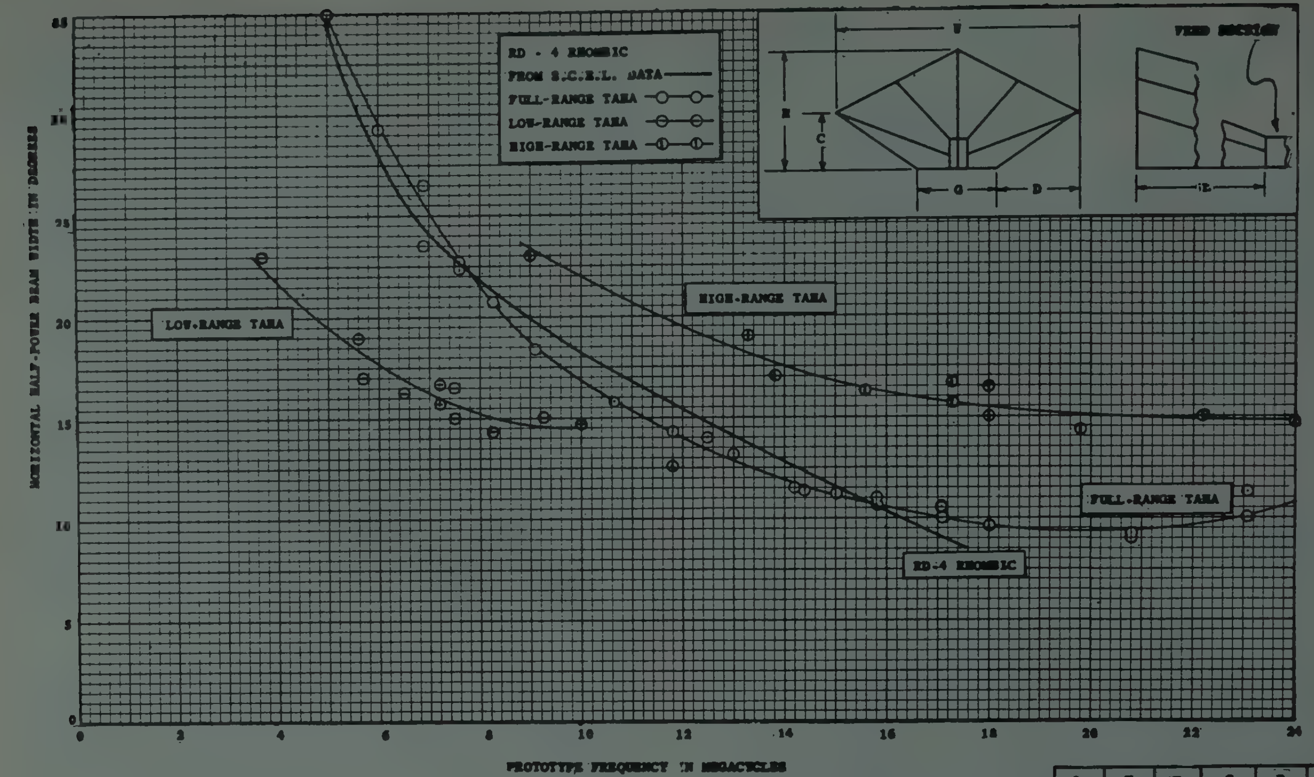
ANTENNA FEED LINES

Antenna feed lines of the balanced open-wire transmission line type are still used almost exclusively in HF transmitting installations, in contrast to receiving installations which are using mostly coaxial cable. One aspect of balanced open-wire lines which has been given little attention is that they act as rather efficient directive radiators if excitation is unbalanced with respect to ground. Such unbalanced excitation can occur unintentionally if the transmitter or the line are not carefully constructed or operated. Relatively small deficiencies suffice to cause strong unbalanced excitation. Yet the provisions presently made for detecting such deficiencies are totally inadequate in almost all installations, both commercial and military, to the knowledge of this author.

This contention is borne out by the vector diagrams of Fig. 7 which show the voltage and current vectors involved in an elementary section of open-wire line for both the left and right-hand side. Fig. 7 illustrates how any given excitation can be split into a perfectly balanced excitation and a pure unbalanced excitation superimposed on each other. From this illustration it becomes obvious, for example, that the left-side currents and right-side currents can be exactly equal in amplitude satisfying one condition for balanced excitation, and that notwithstanding, the unbalanced current component can be strong. A small deviation of the currents from the 180-degree phase relationship suffices for this end. This proves that two ammeters, one in each side of the line, are not sufficient to detect such a situa-

---

[5] R. E. Ankers, B. G. Hagaman, and others, "Reliable High-Frequency Communications," Developmental Engineering Corp., Leesburg, Va., Signal Corps Contract DA-36-039 SC-64486; July, 1956. (See also Sixth through Ninth Progress Reports; November, 1956, through December, 1957.)



	L	U	H	C	D	G
FULL-RANGE TAHA AT 7 MC	844' 6λ	506' 3.6λ	253' 1.8λ	84.5' 0.6λ	169' 1.2λ	169' 1.2λ
LOW-RANGE TAHA AT 5 MC	795' 4.1λ	796' 4.1λ	398' 2.λ	199' 1.λ	265' 1.3λ	265' 1.3λ
HIGH-RANGE TAHA AT 12 MC	334' 4.1λ	334' 4.1λ	167' 2.λ	84' 1.λ	110' 1.3λ	110' 1.3λ

Fig. 6—Horizontal half-power beam width as a function of frequency for TAHA and RD-4 rhombic.

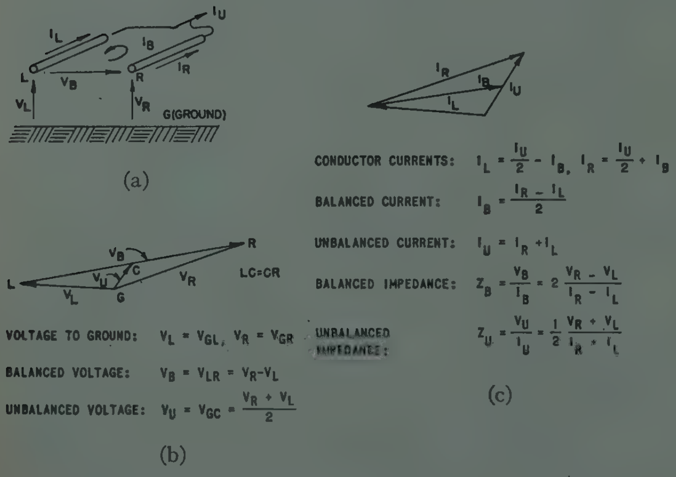
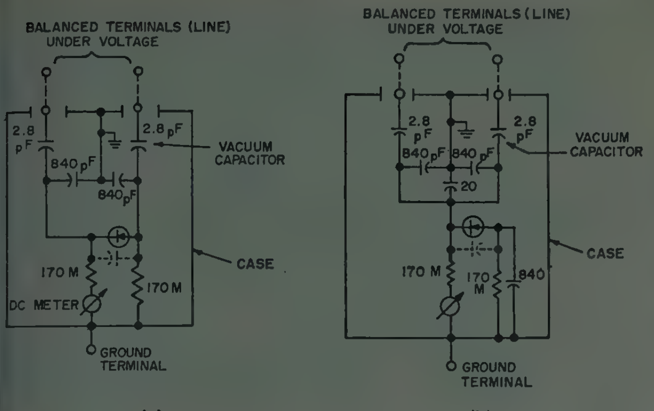

I_U
I_L
I_B
I_R
L
R
V_B
V_L
V_R
G(GROUND)
(a)
R
V_B
C
V_U
V_R
LC=CR
L
V_L
G
VOLTAGE TO GROUND: $V_L = V_{GL}$, $V_R = V_{GR}$
BALANCED VOLTAGE: $V_B = V_{LR} = V_R - V_L$
UNBALANCED VOLTAGE: $V_U = V_{GC} = \frac{V_R + V_L}{2}$
(b)
I_R
I_B
I_U
I_L
CONDUCTOR CURRENTS: $I_L = \frac{I_U}{2} - I_B$, $I_R = \frac{I_U}{2} + I_B$
BALANCED CURRENT: $I_B = \frac{I_R - I_L}{2}$
UNBALANCED CURRENT: $I_U = I_R + I_L$
BALANCED IMPEDANCE: $Z_B = \frac{V_B}{I_B} = 2\frac{V_R - V_L}{I_R - I_L}$
UNBALANCED IMPEDANCE: $Z_U = \frac{V_U}{I_U} = \frac{1}{2}\frac{V_R + V_L}{I_R + I_L}$
(c)

Fig. 7—Relationships in a two-wire line. (a) Assumed directions of voltages and currents. (b) Vector voltages. (c) Vector currents and impedances.

tion. Yet, two ammeters are presently standard equipment for monitoring. The large inaccuracy of RF ammeters, especially when the currents are lower than the full-scale value, permits a strong unbalance to go undetected even if the 180-degree-phase condition is satisfied. With this kind of monitoring equipment it is conceivable that most of the output power of a transmitter is radiated from the line or absorbed in the ground underneath and only little is radiated from the antenna in the normal way, without being noticed. In any case this radiation may greatly exceed the unavoidable radiation of the line originating from the balanced component of the excitation.

The reason why presently used monitoring equipment is inadequate is, by the way, not that adequate equipment is unavailable or too expensive. Fig. 8 shows the circuit diagrams of a commercially available voltmeter in the switch positions "balanced" and "unbalanced" which permit measuring both voltage components directly and separately. Two such instruments a quarter wavelength apart along the line, or one such instrument together with a corresponding one measuring the balanced and unbalanced current components, are necessary to detect unbalanced excitation under all circumstances. However, one instrument alone already would minimize the chances of strong unbalanced excitation going undetected.

Monitoring the degree of balance of the excitation of a line is, of course, only a first step in suppressing radia-



(a) (b)

Fig. 8—Voltmeter for measuring degree of balance of the voltage in a three-terminal network. (a) Measurement of balanced voltage component. (b) Measurement of unbalanced component.

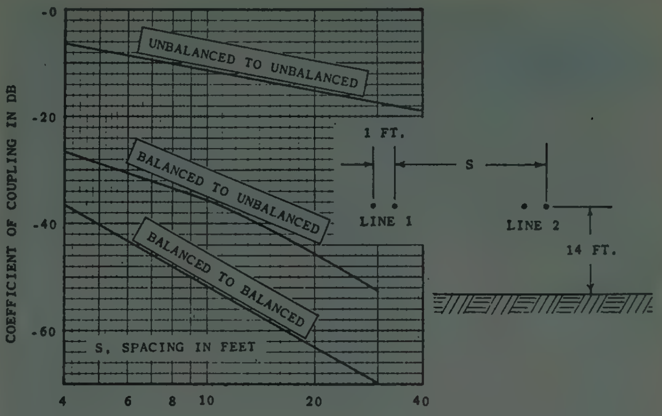


Fig. 9—Coupling between parallel quarter-wave sections of standard 600-ohm line.

tion from it. The next step would be to take corrective measures if the unbalanced excitation exceeded a specified percentage of the balanced excitation. In principle, provisions for adjustment are required in both line and transmitter, although probably in most cases adjustment of the transmitter will suffice. At present, provisions for adjustment do not exist or are not adequate. Incorporating such provisions is not technically difficult, but not a minor modification either from the overall engineering point of view.

It should be mentioned that unbalanced excitation of an open-wire line can also occur through coupling to an adjacent perfectly balanced line, as illustrated in Fig. 9.

In determining the tolerable unbalanced excitation at the line input, one has to consider the resulting radiation from the line together with the antenna in relation to the radiation from the antenna for balanced excitation. It is obvious that the radiation from the line in the direction of the maximum of its radiation pattern at least should not exceed the radiation in the strongest side lobe of the antenna radiation pattern for normal operation. This means that the RF power in the unbalanced excitation should be at least 6 db down from the power in the balanced excitation if a rhombic antenna is used, assuming that the maximum directivity gain of the line together with the antenna for unbalanced excitation is the same as that of the antenna for balanced excitation, and that the power absorbed in the ground is negligible. Higher directivity gain of the line would tend to lower the tolerable unbalance, and strong absorption would permit raising it. Though 6-db minimum required suppression seems to be a very modest goal, it is not sure whether this requirement is met in existing installations. On the other hand, it would be unreasonable to require the radiation of the line resulting from the unbalanced excitation to be lower than that from the balanced excitation. Presently-available information is not sufficient to permit definite conclusions in this respect. It is certain, however, that radiation from open-wire lines due to unintentional unbalanced excitation will become a critical factor when, at some time in the future, effective side-lobe suppression will be required of transmitting antennas. As an indication of how critical it is, it is mentioned that the radiation of conventional lines due to the balanced component of the excitation at 50 mc is only about 20 db down from the radiation in the main beam of an antenna with 25-db gain.

In view of these anticipated difficulties in preventing open-wire lines from radiating, it appears to be simpler and more effective to replace them with shielded lines, which, for the purpose of this discussion, include coaxial cable as well as balanced shielded lines. Two reasons have prevented the adoption of this solution up to now. One was that reliable wide-band transformers for matching the antenna to shielded lines were not available. The other reason was the relatively high cost of shielded lines.

The engineering approach to the economy of feed lines is to compare the annual interest and amortization plus maintenance of different types of lines to the annual ac-power cost, based on a given antenna input power. Into this comparison enter the period of amortization, the interest rate, the absolute value of the antenna power, the efficiency of the transmitter, and the line length. In a recent survey by Developmental Engineering Corporation under contract with these laboratories,[5] it has been shown that, in the case of high antenna power, the shielded balanced line is more economical in the long run than the open-wire line. This survey dispels a prejudice of many radio engineers against shielded lines for feeding transmitting antennas. Although at lower antenna power the shielded line is usually still less economical than the open-wire line, it is believed that the difference is outweighed in many cases by the differences in reliability under severe environmental conditions and in other respects which

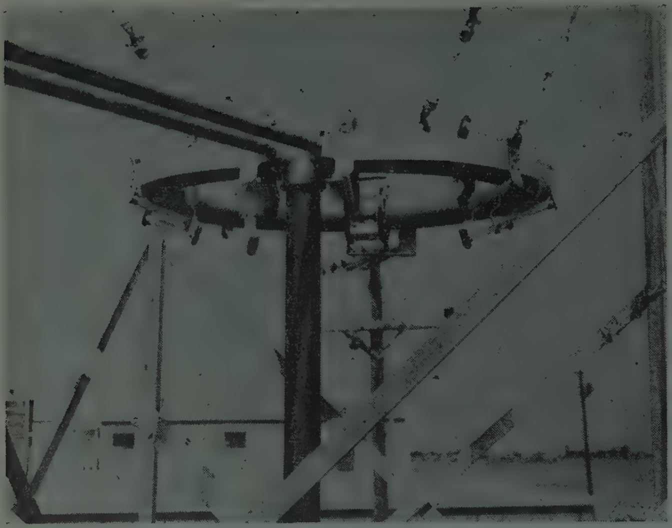


Fig. 10—Experimental broadband balance-unbalance transformer (DECO).

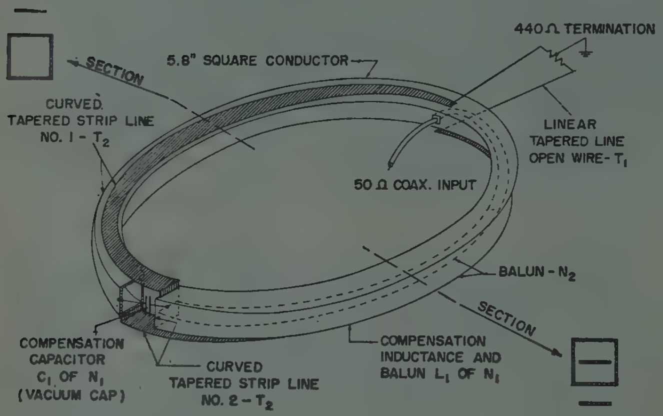

440 Ω TERMINATION
SECTION
5.8" SQUARE CONDUCTOR
CURVED TAPERED STRIP LINE NO. 1 - T_2
LINEAR TAPERED LINE OPEN WIRE - T_1
50 Ω COAX. INPUT
BALUN - N_2
SECTION
COMPENSATION CAPACITOR C_1 OF N_1 (VACUUM CAP)
CURVED TAPERED STRIP LINE NO. 2 - T_2
COMPENSATION INDUCTANCE AND BALUN L_1 OF N_1

Fig. 11—Pictorial view of wide-band matching transformer.

favor shielded lines apart from the interference suppression aspect.

The decisive factor is, of course, the technical feasibility of broad-band matching of shielded lines to the antennas. It can now safely be said that this problem has been solved. Figs. 10 and 11 show a broad-band transformer developed by Developmental Engineering Corporation under contract with these laboratories.[5] It is a modification of a transformer widely used in Germany[6] and designed to match 50 ohms unbalanced to 225 ohms balanced over the frequency range from 4 to 30 mc without any readjustment. It can handle a power of 500-kw cw. Fig. 12 shows that the SWR is less than 1.4 to 1 over the entire range. Transformation to higher impedances can be obtained with an additional section of exponential line relatively short in length, as illustrated in Fig. 13. This example is an extreme case in the sense that it combines an extremely wide frequency range of 1:7.5 and a very high power-handling capability. It has been cited here in order to show that such stringent requirements can be met without difficulty. Of course, even less difficulty is encountered where we have the requirements of smaller frequency ranges and lower-power handling capabilities.

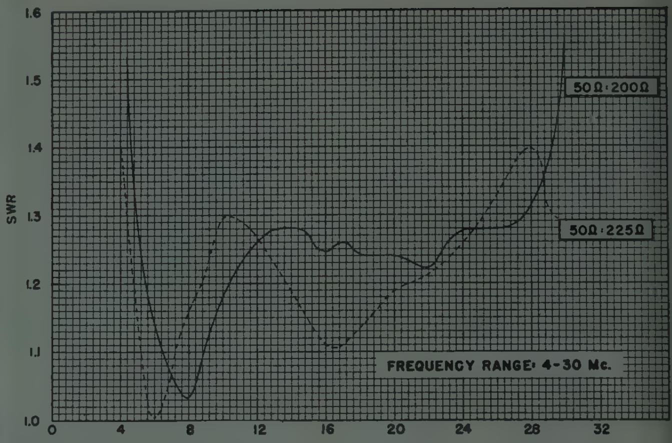


Fig. 12—Standing-wave characteristics of the DECO balum.

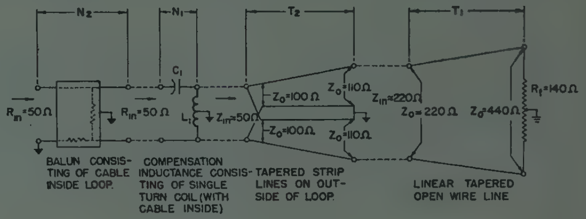

N_2
N_1
T_2
T_1
C_1
$R_{in}=50\Omega$
$R_{in}=50\Omega$
L_1
$Z_{in}=50\Omega$
$Z_0=100\Omega$
$Z_0=100\Omega$
$Z_0=110\Omega$
$Z_0=110\Omega$
$Z_{in}=220\Omega$
$Z_0=220\Omega$
$Z_0=440\Omega$
$R_t=140\Omega$
BALUN CONSISTING OF CABLE INSIDE LOOP.
COMPENSATION INDUCTANCE CONSISTING OF SINGLE TURN COIL (WITH CABLE INSIDE)
TAPERED STRIP LINES ON OUTSIDE OF LOOP.
LINEAR TAPERED OPEN WIRE LINE

Fig. 13—Functional analysis of wide-band transformer.

---

[6] W. Berndt, "Transportation of energy to the antennas of shortwave overseas stations," *Telefunken Zeitung*, vol. 27, nos. 104, 105; July, 1954.

* * *

Optimum Noise Performance of Linear Amplifiers*

H. A. HAUS†, ASSOCIATE MEMBER, IRE, AND R. B. ADLER†, SENIOR MEMBER, IRE

Summary—**A single quantitative measure of amplifier spot noise erformance is established. It removes difficulties heretofore as-ociated with the effect of feedback upon spot noise performance. his measure, $(M_e)_{\mathrm{opt}}$, is a function of the amplifier noise and circuit arameters alone. It determines the lowest spot noise figure achiev-ble *at high gain* with a given amplifier, which is used either alone r in a passive interconnection with other amplifiers of the same $M_e)_{\mathrm{opt}}$. Moreover, passive interconnection of amplifiers with differ-nt $(M_e)_{\mathrm{opt}}$ cannot lead to a spot noise figure at high gain better than hat obtainable by using only amplifiers of the smallest $(M_e)_{\mathrm{opt}}$. $M_e)_{\mathrm{opt}}$ is, therefore, a valid measure of the absolute quality of am-lifier noise performance.**

In many important cases the best noise performance attainable vith a particular type of amplifier is actually achieved by a simple ascade in which the input of each stage is properly mismatched. The nismatch conditions for each stage do not in general coincide with hose normally used to "minimize" its noise figure.

In the case of a two-terminal-pair negative resistance amplifier, limiting form of which is the maser, optimization may always be btained using an ideal circulator.

I. INTRODUCTION

IT IS common practice to describe the single-frequency noise performance of an amplifier in terms of its "spot noise figure," and it is well known that his figure is a function of the impedance of the source onnected to the amplifier input. Thus, in giving an dequate conventional description of amplifier noise erformance, the source impedance, as well as the noise igure, must be specified.

Usually, when regarded as a function of source im-edance alone, the noise figure has a minimum value or some particular choice of this impedance. If with his source impedance the gain of a given amplifier *emains sufficiently large*, its noise figure will prescribe the noise figure of any amplifier cascade in which it is used as the first stage. In this way, it is possible to build an amplifier cascade with any desired high gain, and with a noise figure set by the minimum (with respect to source impedance) of the noise figure of the original amplifier.

If a cascade is to be composed of several individual amplifiers, each of which alone has a "high enough" gain when driven from the source impedance that yields its minimum noise figure, the previous argument shows that the amplifier with the lowest minimum noise figure should be used as the first stage. Any other choice would result in a higher over-all noise figure for the cascade.

The foregoing discussion seems to suggest that the minimum value (with respect to source impedance) of the noise figure of an amplifier may be used as an adequate criterion of its noise performance, and as a basis for comparison with other amplifiers. The validity of the argument, however, is based upon the two previously mentioned restrictions:

1) each stage has "*high enough*" *gain* when driven from the "optimum" source that yields the minimum noise figure; and
2) only the *source impedance* of each stage is varied in controlling the noise performance.

Unfortunately, stage variables other than source impedance, and stage interconnections other than the simple cascade, may be important in amplifier applications. The question of the quality of noise performance then becomes much more complicated. For example, when degenerative feedback is applied to an amplifier, its noise figure can be reduced to as close to unity as desired (*e.g.*, by-passing the entire amplifier with short circuits yields unit noise figure). But its gain is also reduced in the process. Indeed, if identical stages with the feedback are cascaded to recover the original single-stage gain before feedback, the resulting noise figure of the cascade cannot be less than that of the original amplifier [1]. Moreover, with degenerative feedback the gain may easily be so greatly reduced that, as a first stage in a cascade, this amplifier alone no longer determines the over-all noise figure of the cascade. The criterion considered above as a measure of amplifier noise performance breaks down. It appears that the characterization of amplifier quality must include, in addition to the specification of noise figure and source impedance, at least the specification of the gain.

The purpose of this paper is to develop a reasonable single quantitative measure of amplifier noise performance, which must involve both noise figure and gain. Our suggested criterion for characterizing amplifier quality is based on the plausible premise that, basically, amplifiers are supposed to provide "gain building blocks" without adding excessively to *system* noise. On this basis the following criterion is adopted.

Suppose that n different types of amplifiers are compared. An unlimited number of amplifiers of each type is presumed to be available. A general *lossless* (possibly nonreciprocal) interconnection of an arbitrary number of amplifiers of each type is then envisioned, with terminals so arranged that in each case an over-all *two-terminal-pair network* is achieved. For each amplifier type, both the lossless interconnecting network and

---

* Original manuscript received by the IRE, June 17, 1957. This work was supported in part by the U. S. Army (Signal Corps), the U. S. Air Force (Office of Scientific Res., Air Res. and Dev. Command), and the U. S. Navy (Office of Naval Res.).

† Dept. of Elec. Eng. and Res. Lab. of Electronics, Mass. Inst. Tech., Cambridge, Mass.

the number of amplifiers are varied in all possible ways to produce two conditions simultaneously:

1) a very high available gain (approaching infinity) for the over-all two-terminal-pair system when driven from a source having a positive real internal impedance; and
2) an absolute minimum noise figure $F_{\min}$ for the resulting high-gain system.

The value of $(F_{\min}-1)$ *for the resulting high-gain two-terminal-pair network is taken specifically as the "measure of quality" of the amplifier type in each case. The "best" amplifier type will be the one yielding the smallest value of* $(F_{\min}-1)$ *at very high gain.*

The justification for this quality criterion hinges upon four theorems, the demonstration of which forms the body of this paper.

1) $F_{\min}$ at arbitrarily high gain *exists* under the above required conditions for any amplifier type, and can be calculated in a direct manner from the amplifier noise and circuit parameters.
2) Passive dissipative interconnection of several given amplifiers never yields a lower $F_{\min}$ (at arbitrarily high gain) than that achievable with lossless interconnections.
3) The $F_{\min}$ achievable at large gain with an interconnection of amplifiers of different types can never be lower than that achievable when only amplifiers of best quality are used.
4) Circuit connections exist for achieving $F_{\min}$ at high gain with any amplifier type. They depend to some extent upon the class of amplifier in question, and are not necessarily unique.

Before we can prove the theorems, however, certain rather new concepts must be introduced [2]–[4]:

1) Exchangeable power, P_e;
2) Exchangeable power gain, G_e;
3) Modification of the noise figure definition to conform with concepts 1 and 2; and
4) Noise measure, M (or M_e).

We shall first consider some elementary cascading ideas leading to the notion of noise measure, and next the question of exchangeable power and related quantities. A matrix formulation of the foregoing new concepts will then be carried out, which will lead to the four major theorems.

II. Cascading of Amplifiers and Noise Measure

The simplest interconnection of amplifiers for achieving high gain is the cascade connection. A brief review of the conventional theory of noise performance in a cascade connection, when the component amplifiers do *not* necessarily have large gain, actually furnishes a major clue to introducing the noise measure concept and to solving the entire problem of characterizing the quality of amplifier noise performance.

Suppose that two amplifiers with noise figures F_1 and F_2 and available gains $G_1(>1)$ and $G_2(>1)$ are to be cascaded. The question is: Which amplifier should be used as the input stage in order to achieve the smallest over-all noise figure of the cascade? For simplicity, suppose that the noise figures F_1 and F_2 and the available gains G_1 and G_2 *are independent of the order of cascading.* When amplifier 1 is at the input, the over-all noise figure is

$$F_{12} = F_1 + \frac{F_2 - 1}{G_1}\cdot \tag{1}$$

When amplifier 2 is at the input, we find

$$F_{21} = F_2 + \frac{F_1 - 1}{G_2}\cdot \tag{2}$$

The condition $F_{12} < F_{21}$ dictates that amplifier 1 should be first in the cascade. For this condition,

$$F_1 + \frac{F_2 - 1}{G_1} < F_2 + \frac{F_1 - 1}{G_2}$$

or, if we subtract 1 from both sides and rearrange, we have

$$\frac{F_1 \quad - 1}{1 - \dfrac{1}{G_1}} < \frac{F_2 \quad - 1}{1 - \dfrac{1}{G_2}}\cdot$$

Thus, the cascade connection of the two amplifiers will have the smaller noise figure when the amplifier with the smaller value, not of F, but of the quantity

$$M = \frac{F - 1}{1 - \dfrac{1}{G}} \tag{3}$$

is placed first in the cascade.

It is reasonable to expect from the above result, and from the considerations set forth in the Introduction, that M will play an important role in determining the quality of amplifier noise performance. Indeed, it is essentially M that we have called the "noise measure."

The cascading formula expressed in terms of M, rather than F, has the form

$$M_{12} \equiv \frac{F_{12} - 1}{1 - \dfrac{1}{G}} = M_1 + (M_2 - M_1)\frac{G_2 - 1}{G - 1}, \tag{4}$$

where $G = G_1G_2$ is the gain of the cascaded pair. The noise measure, from (4), has the significant property that two amplifiers of equal M (but possibly different gains) connected in cascade result in an over-all amplifier with the same M. Therefore, if an amplifier has a noise measure M, an available gain $G>1$, and a positive output impedance, a cascade of many identical amplifiers with suitable matching transformers leads to an over-all amplifier of arbitrary large gain and the same M. The excess noise figure of the over-all amplifier is $F-1=M$. In these cases the physical significance of M is: the excess noise figure at large gain. It is through an extension of this property of M to more general cases that we shall be able to deal analytically with the noise performance criterion introduced in Section I.

It will also be necessary to know that: the noise measure M of a *passive* two-terminal-pair network in thermal equilibrium at temperature T is just -1. This is proved by the following argument. On thermodynamic grounds, the total noise power available at the output terminals must be $kT\Delta f$, if a passive impedance at equilibrium temperature T is at the input. But the available noise power at the output is also $FGkT\Delta f$, from the definition of F. Therefore, $FG=1$ and $M=-1$.

III. Extended Definitions of Gain, Noise Figure, and Noise Measure

Any general theory of linear active networks must include situations involving negative resistance. However, the conventional notion of the "available power" of a source leads to singular values or complete indeterminacy in the theory of cases that are perfectly meaningful in the final outcome.

We therefore propose to use a new concept, the *exchangeable power* of a source, to replace the conventional term "available power." An obvious modification of "available power gain" to *exchangeable power gain*, and a corresponding revision of the noise figure definition (on the basis of exchangeable gain and exchangeable power) follow immediately from the new concept. The underlying needs, and the reasons for our choice of the specific definition of exchangeable power given below are discussed elsewhere at length [4]; here we present only a summary to make the present paper self-contained.

A. Exchangeable Power

Definition: The *exchangeable power* $P_e(\lessgtr 0)$ of a two-terminal linear network is the *stationary* value of its power output, regarded as a function of its terminal current (or voltage).

In terms of the Thévenin representation of this network, comprising an rms open-circuit terminal voltage E_S and an internal (source-free) impedance $Z_S=R_S+jX_S$, our definition can be shown to yield

$$P_e = \frac{|E_S|^2}{4R_S}; \quad R_S \neq 0. \tag{5}$$

When $R_S>0$, (5) gives for $P_e(>0)$, the conventional available power of the network, which is also the greatest power obtainable *from* it by arbitrary variation of the load impedance. The optimum load for this purpose is the (passive) impedance Z_S^*. When $R_S<0$, however, $P_e(<0)$ represents in magnitude the greatest power that can be pushed *into* the "source" network by arbitrary variation of the (possibly nonpassive) "load" impedance. The optimum load for this purpose is the (nonpassive) impedance Z_S^*, which actually pushes power *into* the original network (hence the negative value of P_e).

We note, incidentally, that the conventional available power of a network with any value of $R_S<0$ (and $E_S\neq 0$) would always be *infinite* [achieved under (passive) load conditions $-Z_S$]. This is an awkward singular result; and it is at variance with both our present definition of P_e and the corresponding equation (5). One obvious advantage of the exchangeable power concept is that it retains an invariant analytical expression in all cases for which it is defined.

B. Exchangeable Power Gain

The *exchangeable power gain* G_e of a two-terminal-pair network is now defined from the exchangeable power P_{eS} of the input source and the exchangeable power P_{eO} at the network output. Specifically,

$$G_e = \frac{P_{eO}}{P_{eS}}. \tag{6}$$

If $Z_S=R_S+jX_S$ is the source impedance, and $Z_O=R_O+jX_O$ is the output impedance of the network with the source impedance Z_S connected at the input, we find that

$$G_e > 0 \quad \text{if} \quad R_S/R_O > 0 \tag{7a}$$

$$G_e < 0 \quad \text{if} \quad R_S/R_O < 0. \tag{7b}$$

Observe that when $R_S>0$ and $R_O>0$, G_e becomes the conventional available gain of the two-terminal-pair network.

C. Extended Noise Figure and Noise Measure

The foregoing ideas lead to an extended definition F_e, of the noise figure of a two-terminal-pair network

$$F_e = 1 + \frac{N_{ei}}{G_e kT\Delta f}, \tag{8}$$

where N_{ei} is the exchangeable noise power at the network output when the source has a given (noiseless) impedance Z_S. Thus N_{ei} contains only the effect of *internal* network noise sources. The use of $kT\Delta f$ in (8) represents merely an arbitrary (but convenient) normalization factor for cases in which the source impedance has a *negative* real part. Otherwise it represents physically the available noise power from a passive impedance at thermal equilibrium temperature T.

From (5)–(8), it is clear that

$$F_e - 1 > 0 \quad \text{if} \quad R_S > 0 \tag{9a}$$

$$F_e - 1 < 0 \quad \text{if} \quad R_S < 0. \tag{9b}$$

If $R_S>0$ and $R_O>0$, F_e becomes the standard noise figure F. It is easy to show that cascading formulas (1) and (2) always remain valid when F and G are replaced by F_e and G_e [4].

The generalized form of the noise measure M introduced in (3) becomes

$$M_e = \frac{F_e - 1}{1 - \frac{1}{G_e}}. \tag{10}$$

The algebraic sign properties of M_e are summarized in Table I. With reference to Table I it should be pointed out that with $R_S > 0$, conventional available gain greater than 1 occurs in only two ways

1) $G_e > 1$, and
2) $G_e < 0$.

TABLE I

ALGEBRAIC SIGNS OF EXCHANGEABLE GAIN AND DERIVED QUANTITIES

R_S	R_O	G_e	$F_e - 1$	$\lvert G_e \rvert$	M_e
>0	>0	>0	>0	>1	>0
>0	>0	>0	>0	<0	<0
>0	<0	<0	>0	$\gtrless 1$	>0
<0	>0	<0	<0	$\lessgtr 1$	<0
<0	<0	>0	<0	>1	<0
<0	<0	>0	<0	<1	>0

Case 1 holds whenever the amplifier has an output impedance with positive real part and an available (or exchangeable) gain greater than one. Case 2 corresponds to an amplifier with an output impedance having a negative real part. Such an amplifier has an infinite available gain in the conventional sense. In both cases *M_e is found to be greater than zero.* Since we are only interested in amplifiers driven from positive source resistance and with a conventional available gain greater than one, *only positive values of M_e are of interest.*

Suppose therefore that the amplifier has some value of $M_e > 0$. Let us relate the excess noise figure to M_e. In case 1, we find that the excess noise figure is

$$F_e - 1 = F - 1 = \left(1 - \frac{1}{G}\right) M_e.$$

Thus, the excess noise figure of the amplifier is *less* than M_e by a gain-dependent factor $1 - (1/G)$. Cascading of identical amplifiers of this type leads to an amplifier of large gain, with the excess noise figure $F - 1 = M_e$ (see Section II).

In case 2, we obtain, since $G_e < 0$,

$$F_e - 1 = F - 1 = \left(1 + \left|\frac{1}{G_e}\right|\right) M_e.$$

Now the excess noise figure is *greater* than M_e by the factor $(1 + 1/|G_e|)$. The conventional available gain of the amplifier is infinite, and cascading is unnecessary. The above expression is already the excess noise figure at high gain.

The argument that follows is based upon the aforementioned properties of M_e. It will be shown (among other things) that under a very general class of external passive circuit operations upon the terminals of a given amplifier, the possible *positive* values of M_e for the resulting system have a lower bound $(M_e)_{\text{opt}}$. It will also be shown that this lower bound can always be achieved with suitable auxiliary passive networks, in such a way that the output impedance of the altered amplifier has a positive real part. Thus, by repeated cascade, with suitable interstage coupling, the available gain can be increased arbitrarily and the final excess noise figure at large gain becomes just $(M_e)_{\text{opt}}$. We will also show that no other arrangement of this type of amplifier can yield a lower value of noise figure at large gain.

IV. MATRIX FORMULATION OF EXCHANGEABLE POWER AND RELATED QUANTITIES

In order to deal effectively with the envisaged general network interconnections of amplifiers, it is necessary to put into matrix form important amplifier quantities: exchangeable power, exchangeable power gain, and noise measure.

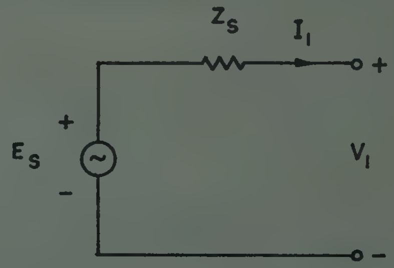


Fig. 1—Thévenin equivalent of two-terminal linear source.

A. Exchangeable Power

A linear two-terminal source of power can be represented by its Thévenin rms open-circuit voltage E_S, in series with its internal impedance Z_S. Let V_1 and I_1 be the terminal voltage and current of the source (see Fig. 1), so that

$$V_1 + Z_S I_1 = E_S. \tag{11}$$

To express (11) in matrix form suitable for cascade applications, define column vectors (matrices) v and x

$$v = \begin{bmatrix} V_1 \\ I_1 \end{bmatrix}; \quad x = \begin{bmatrix} 1 \\ Z_S^* \end{bmatrix} \tag{12}$$

and let the "dagger" (†) designate the complex conjugate of the transpose of any matrix. Then, for (11), we have

$$x^\dagger v = E_S. \tag{13}$$

Since multiplication of (13) by a constant c does not alter it, we can, purely as a matter of form, always make a new column vector

$$y = \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = cx = \begin{bmatrix} c \\ cZ_S^* \end{bmatrix}$$

and a new scalar

$$\gamma = cE_S,$$

so that the source equation (13) becomes

$$v^\dagger v = \gamma \tag{14a}$$

with

$$y_2/y_1 = Z_S^*, \tag{14b}$$

where Z_S is still the internal impedance of the source. This formal multiplication feature of the source equation is sometimes helpful in interpreting the following analyses.

Now the exchangeable power P_e of the source may be written in matrix form

$$P_e = \frac{|E_S|^2}{2(Z_S + Z_S^*)} = \frac{|E_S|^2}{2(x^\dagger P x)} = \frac{|\gamma|^2}{2(y^\dagger P y)} \tag{15}$$

where the square "permutation" matrix P is defined as

$$P = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \tag{16}$$

with properties $P^\dagger = P$ and $P^{-1} = P$. The usefulness of the last expression in (15) lies in the fact that it can be written by inspection for any two-terminal source with a source equation in the form of (14).

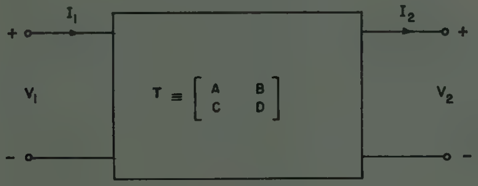


Fig. 2—Two-terminal-pair linear source-free network.

B. Exchangeable Power Gain

Consider a linear source-free two-terminal-pair network, described by its general-circuit constants A, B, C, D (see Fig. 2). If v is the "input" column vector defined by (12), and we let u be the "output" column vector,

$$u = \begin{bmatrix} V_2 \\ I_2 \end{bmatrix}, \tag{17a}$$

and T is the general circuit matrix,

$$T = \begin{bmatrix} A & B \\ C & D \end{bmatrix}, \tag{17b}$$

the network equations are expressed in matrix form as

$$v = Tu. \tag{18}$$

When the network of Fig. 2 is driven by the source of Fig. 1, the exchangeable output power P_{eO} from terminal pair 2 can be obtained at once from a source equation in the form of (14) written with u as column variable. Multiplication of (18) by $y^\dagger$, with the use of (14), yields this new relation,

$$(y^\dagger T)u = \gamma. \tag{19}$$

Accordingly, by applying the steps of (14)–(16) to (19), we find that

$$P_{eO} = \frac{|\gamma|^2}{2y^\dagger TPT^\dagger y} \tag{20}$$

and with (15) and (6), for the exchangeable gain we have

$$G_e = \frac{y^\dagger P y}{y^\dagger TPT^\dagger y}. \tag{21}$$

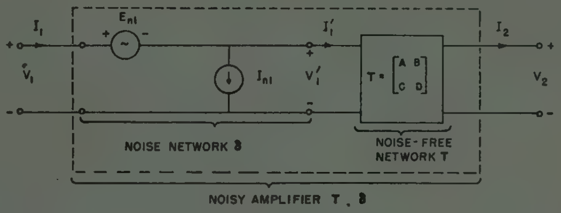


Fig. 3—Two-terminal-pair linear network with internal sources.

C. Extended Noise Figure and Noise Measure

To apply the matrix formulation of exchangeable power to the calculation of the (extended) noise figure of a two-terminal-pair noisy network, we still describe the network by its general-circuit constants, but we also allow for noise voltages or currents at the terminals in the absence of external sources. With reference to Fig. 3, the network equations for the dotted box [5] would be

$$v = Tu + \delta \tag{22}$$

with δ a "noise column vector,"

$$\delta = \begin{bmatrix} E_{n1} \\ I_{n1} \end{bmatrix}. \tag{23}$$

Actually, for noise processes, the complex amplitudes E_{n1} and I_{n1} are only of formal significance, the important physical concepts being the self- and cross-power density spectra, which are summarized in the convenient matrix form

$$\overline{\delta\delta^\dagger} = \begin{bmatrix} \overline{E_{n1}E_{n1}^*} & \overline{E_{n1}I_{n1}^*} \\ \overline{I_{n1}E_{n1}^*} & \overline{I_{n1}I_{n1}^*} \end{bmatrix} \tag{24}$$

which is Hermitian and positive definite (or semidefinite).

Now (22) can be rewritten as two relations:

$$v' = Tu \tag{25a}$$

$$v = v' + \delta. \tag{25b}$$

If we visualize

$$v' = \begin{bmatrix} V_1' \\ I_1' \end{bmatrix}$$

as referring simultaneously to the input terminals of a noise-free network $\boldsymbol{T}$ and the output terminals of a pure noise network $\boldsymbol{\delta}$, the cascade division of the system is represented in Fig. 3. The noiseless part $\boldsymbol{T}$ does not affect the noise figure of the system. Thus, for noise figure calculations, we need only consider the noise network $\boldsymbol{\delta}$ driven by a source of internal impedance Z_S [5].

The source equation appropriate to the right-hand terminals in Fig. 4 can be obtained from (25b) and (14) with $E_S=0$.

$$\boldsymbol{v}^\dagger \boldsymbol{v}' = -\boldsymbol{y}^\dagger \boldsymbol{\delta}. \tag{26}$$

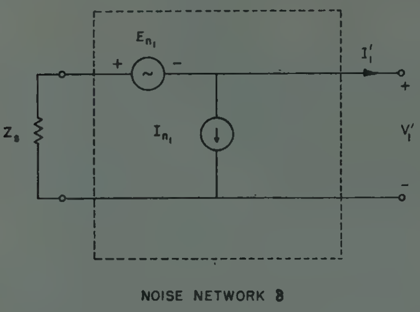


Fig. 4—Essentials of Fig. 3 for determination of noise figure.

Therefore, the output exchangeable power, N_{ei}, produced by the internal noise only, is given by

$$N_{ei} = \frac{\boldsymbol{y}^\dagger \overline{\boldsymbol{\delta}\boldsymbol{\delta}^\dagger} \boldsymbol{y}}{2\boldsymbol{y}^\dagger \boldsymbol{P} \boldsymbol{y}} \tag{27}$$

and, since $G_e=1$ for this network, we have

$$F_e - 1 = \frac{N_{ei}}{kT\Delta f} = \frac{\boldsymbol{y}^\dagger \overline{\boldsymbol{\delta}\boldsymbol{\delta}^\dagger} \boldsymbol{y}}{\boldsymbol{y}^\dagger \boldsymbol{P} \boldsymbol{y}(2kT\Delta f)}. \tag{28}$$

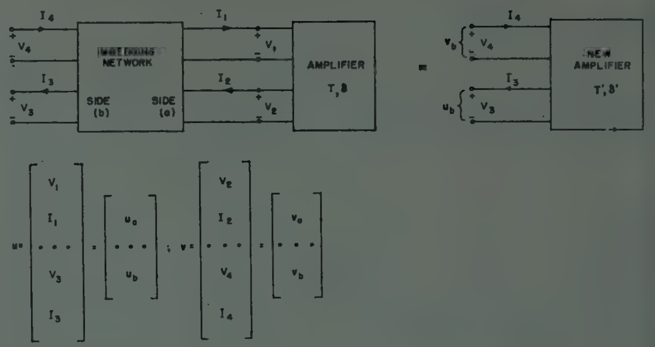
Finally, in view of (10), (21), and (28) the noise measure becomes

$$M_e = \frac{\boldsymbol{y}^\dagger \overline{\boldsymbol{\delta}\boldsymbol{\delta}^\dagger} \boldsymbol{y}}{\boldsymbol{y}^\dagger(\boldsymbol{P} - \boldsymbol{T}\boldsymbol{P}\boldsymbol{T}^\dagger)\boldsymbol{y}}\left(\frac{1}{2kT\Delta f}\right). \tag{29}$$

V. EXTREMAL PROPERTY OF THE NOISE MEASURE

The properties of the noise measure M_e are the bases upon which we build the quality criterion of amplifier noise performance given in the Introduction. Recall that only positive values of M_e are of interest (see Section III-C). We shall first show that M_e, for a two-terminal-pair network, has a minimum positive value with regard to *all* lossless (possibly nonreciprocal) transformations that can be performed on the original network so as to obtain a new two-terminal-pair network from it.

The most general lossless transformation of the kind described above is shown in Fig. 5. It consists of an "imbedding" of the original network into a four-terminal-pair network. Such a network can be represented conveniently in a modified general-circuit matrix notation, by using two matrix equations (see Appendix 1):



I_4
V_4
I_3
V_3
IMBEDDING NETWORK
SIDE (b)
SIDE (a)
I_1
V_1
I_2
V_2
AMPLIFIER
T, δ
=
v_b
u_b
I_4
V_4
I_3
V_3
NEW AMPLIFIER
T', δ'
$u = \begin{bmatrix} V_1 \\ I_1 \\ \cdots \\ V_3 \\ I_3 \end{bmatrix} = \begin{bmatrix} u_a \\ \cdots \\ u_b \end{bmatrix}; \quad v = \begin{bmatrix} V_2 \\ I_2 \\ \cdots \\ V_4 \\ I_4 \end{bmatrix} = \begin{bmatrix} v_a \\ \cdots \\ v_b \end{bmatrix}$

Fig. 5—Imbedding of two-terminal-pair amplifier for production of a new two-terminal-pair amplifier.

$$\boldsymbol{v}_a = \boldsymbol{T}_{aa}\boldsymbol{u}_a + \boldsymbol{T}_{ab}\boldsymbol{u}_b \tag{30}$$

$$\boldsymbol{v}_b = \boldsymbol{T}_{ba}\boldsymbol{u}_a + \boldsymbol{T}_{bb}\boldsymbol{u}_b. \tag{31}$$

If the imbedding network is lossless, it cannot contain internal noise, and therefore (30) and (31) contain no terms representing internal sources.

The original two-terminal-pair amplifier imposes a relation upon the column vectors $\boldsymbol{v}_a$ and $\boldsymbol{u}_a$. If we observe, from Fig. 5, that for this amplifier network the meanings of $\boldsymbol{T}$ and $\boldsymbol{\delta}$ will only be consistent with our previous definition of them (see Figs. 2–4), and if we now regard $\boldsymbol{v}_a$ as an *output* and $\boldsymbol{u}_a$ as an *input*, we have

$$\boldsymbol{u}_a = \boldsymbol{T}\boldsymbol{v}_a + \boldsymbol{\delta}. \tag{32}$$

If (32) is introduced into (30) and (31), we can find a relation between $\boldsymbol{v}_b$ and $\boldsymbol{u}_b$. This is the relation characterizing a new two-terminal-pair amplifier with output $\boldsymbol{u}_b$, input $\boldsymbol{v}_b$, general-circuit matrix $\boldsymbol{T}'$, and noise vector $\boldsymbol{\delta}'$ (see Fig. 5).

$$\boldsymbol{v}_b = \boldsymbol{T}'\boldsymbol{u}_b + \boldsymbol{\delta}' \tag{33}$$

with

$$\boldsymbol{T}' = \boldsymbol{T}_{ba}(\boldsymbol{I} - \boldsymbol{T}\boldsymbol{T}_{aa})^{-1}\boldsymbol{T}\boldsymbol{T}_{ab} + \boldsymbol{T}_{bb} \tag{34}$$

and

$$\boldsymbol{\delta}' = \boldsymbol{T}_{ba}(\boldsymbol{I} - \boldsymbol{T}\boldsymbol{T}_{aa})^{-1}\boldsymbol{\delta}, \tag{35}$$

where $\boldsymbol{I}$ is the identity matrix.

To determine the effect of imbedding upon the noise measure (29), we have to determine its effect upon $\overline{\boldsymbol{\delta}\boldsymbol{\delta}^\dagger}$ and $\boldsymbol{P}-\boldsymbol{T}\boldsymbol{P}\boldsymbol{T}^\dagger$. First, from (35), it follows that

$$\overline{\boldsymbol{\delta}'\boldsymbol{\delta}'^\dagger} = \boldsymbol{Q}\overline{\boldsymbol{\delta}\boldsymbol{\delta}^\dagger}\boldsymbol{Q}^\dagger, \tag{36}$$

where

$$\boldsymbol{Q} = \boldsymbol{T}_{ba}(\boldsymbol{I} - \boldsymbol{T}\boldsymbol{T}_{aa})^{-1}. \tag{37}$$

Next, from (34) and (37), we have

$$\begin{aligned} \boldsymbol{P} - \boldsymbol{T}'\boldsymbol{P}\boldsymbol{T}'^\dagger &= \boldsymbol{P} - (\boldsymbol{Q}\boldsymbol{T}\boldsymbol{T}_{ab} + \boldsymbol{T}_{bb})\boldsymbol{P}(\boldsymbol{T}_{bb}^\dagger + \boldsymbol{T}_{ab}^\dagger\boldsymbol{T}^\dagger\boldsymbol{Q}^\dagger) \\ &= \boldsymbol{Q}[\boldsymbol{Q}^{-1}\boldsymbol{P}\boldsymbol{Q}^{-1\dagger} - (\boldsymbol{T}\boldsymbol{T}_{ab} + \boldsymbol{Q}^{-1}\boldsymbol{T}_{bb})\boldsymbol{P}(\boldsymbol{T}_{bb}^\dagger\boldsymbol{Q}^{-1\dagger} \\ &\qquad + \boldsymbol{T}_{ab}\boldsymbol{T}^\dagger]\boldsymbol{Q}^\dagger. \end{aligned} \tag{38}$$

Now, since the imbedding network is lossless under our present assumptions, the factor within square brackets

(38) may be transformed by the conditions of losslessness [(64) in Appendix I]. Using them to eliminate T_{bb} and T_{ab} from the brackets in (38), we find that

$$P - T'PT'^{\dagger} = Q[P - TPT^{\dagger}]Q^{\dagger}. \tag{39}$$

That is, under a *lossless* transformation the matrices $\overline{\delta\delta^{\dagger}}$ and $P - TPT^{\dagger}$ transform in exactly the same manner!

Consider the noise measure, as given by (29), of an amplifier network (T, δ) fed by a source of internal impedance Z_S. If the amplifier is imbedded in a lossless network in the manner of Fig. 5, the resulting new amplifier (T', δ') will have the new noise measure

$$M_e' = \frac{y^{\dagger}Q\overline{\delta\delta^{\dagger}}Q^{\dagger}y}{y^{\dagger}Q[P - TPT^{\dagger}]Q^{\dagger}y}\left(\frac{1}{2kT\Delta f}\right), \tag{40}$$

in view of (36) and (39). When the lossless network is varied through all possible forms, Q might be expected to vary accordingly. The surprising fact is that $Q = T_{ba}(I - TT_{aa})^{-1}$ is *unrestricted* by the conditions of losslessness [(64) in Appendix I]. Indeed, T_{ba} can be chosen quite arbitrarily for a lossless network, and (64) will only serve to determine T_{aa}, T_{bb}, and T_{ab}.

As Q is varied, M_e' may assume various values, depending upon the forms of $\overline{\delta\delta^{\dagger}}$ and $P - TPT^{\dagger}$. As mentioned previously, the noise spectral matrix $\overline{\delta\delta^{\dagger}}$ is positive (semi) definite. But, as far as the matrix $P - TPT^{\dagger}$ is concerned, three cases have to be distinguished (see Appendix I):

1) $P - TPT^{\dagger}$ is positive (semi) definite; T is the general-circuit matrix of a negative-resistance network; $M_e' \geq 0$.
2) $P - TPT^{\dagger}$ is negative (semi) definite; T is the general-circuit matrix of a passive network; $M_e' \leq 0$.
3) $P - TPT^{\dagger}$ is indefinite; T is the general-circuit matrix of a network capable of absorption, as well as delivery of power; $M_e' \gtrless 0$.

When Q in (40) is varied through all possible values, it is shown in Appendix II that M_e' reaches two extrema which are the two eigenvalues of the "characteristic noise matrix"

$$N = \tfrac{1}{2}[P - TPT^{\dagger}]^{-1}\overline{\delta\delta^{\dagger}} \tag{41}$$

divided by $kT\Delta f$.

With the aid of (36) and (39) it is easy to show that N undergoes a similarity transformation,

$$N' = (Q^{\dagger})^{-1}NQ^{\dagger},$$

under a lossless imbedding of the network. The eigenvalues of N remain unchanged. These extrema limit the range of values of M_e', as shown in Fig. 6, for the three cases.

Now, the situations of most practical importance concern the noise performance of amplifiers driven from sources that have an internal impedance with positive real part. According to Table I, the noise measure is positive when $R_S > 0$ in all cases except $R_O > 0$, $0 < G_e < 1$. This case does not correspond to an amplifier. *Hence we shall be interested in achieving only positive values of* M_e', which occur in cases 1 and 3 of Fig. 6. These cases both have an available gain, G, in the conventional sense, greater than unity ($G = G_e$, if $G_e > 1$; $G = \infty$, if $G_e < 0$).

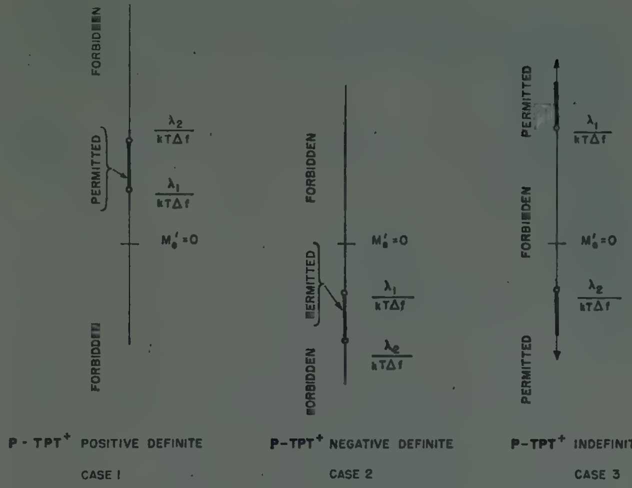

FORBIDDEN
PERMITTED
FORBIDDEN
$\frac{\lambda_2}{kT\Delta f}$
$\frac{\lambda_1}{kT\Delta f}$
$M_e' = 0$
P - TPT⁺ POSITIVE DEFINITE
CASE 1
FORBIDDEN
PERMITTED
FORBIDDEN
$M_e' = 0$
$\frac{\lambda_1}{kT\Delta f}$
$\frac{\lambda_2}{kT\Delta f}$
P-TPT⁺ NEGATIVE DEFINITE
CASE 2
PERMITTED
FORBIDDEN
PERMITTED
$\frac{\lambda_1}{kT\Delta f}$
$M_e' = 0$
$\frac{\lambda_2}{kT\Delta f}$
P-TPT⁺ INDEFINITE
CASE 3

Fig. 6—Schematic of permitted values of M_e' for two-terminal-pair network.

Observe from (40) that the numerator is never negative. Therefore changes in sign of M_e' occur with those of the denominator. In case 3, which includes most conventional amplifiers, M_e' changes sign only at a zero of the denominator.[1] Thus, the values of M_e' cannot lie between $\lambda_1/kT\Delta f$ and $\lambda_2/kT\Delta f$.

The two cases of interest, cases 1 and 3 of Fig. 6, have a *least positive* eigenvalue of N which we call $\lambda_1 > 0$. We have therefore proved the following theorem.

Theorem 1

Consider the set of lossless transformations that carry a two-terminal-pair amplifier into a new two-terminal-pair amplifier with a conventional available gain, G, greater than one. When driven from a source that has an internal impedance with positive real part, the noise measure of the transformed amplifier cannot be less than $\lambda_1/kT\Delta f$, *where* λ_1 *is the smallest positive eigenvalue of the characteristic noise matrix of the original amplifier.*

The fact that $M_e' \geq \lambda_1/kT\Delta f$ also puts a lower limit upon the excess noise figure. Suppose that the amplifier is imbedded in a lossless network, and then connected to a source with an internal impedance having a positive real part. Let the resulting exchangeable power gain be G_e. Then, the excess noise figure of the resulting amplifier has to fulfill the inequality

$$F_e - 1 \geq \frac{\lambda_1}{kT\Delta f}\left(1 - \frac{1}{G_e}\right). \tag{42}$$

---

[1] The elements of T are assumed to be finite. Any difficulties with this assumption [3] can always be avoided by a formulation of the networks in another matrix form.

Thus, an amplifier has a definite lower limit imposed upon its excess noise figure which depends upon the exchangeable power gain achieved in the particular connection.

If $G_e > 0$, *i.e.*, the output impedance of the amplifier has a positive real part, the excess noise figure can be less than $\lambda_1/kT\Delta f$ only to the extent of the gain-dependent factor $(1-1/G_e)$.

If $G_e < 0$, *i.e.*, the output impedance has a negative real part, the lower limit to the excess noise figure is higher than $\lambda_1/kT\Delta f$ by $(1+|1/G_e|)$.

Thus, if there exist two amplifiers with the same eigenvalues of their characteristic noise matrices, (41), *one with a positive output impedance, and the other with a negative output impedance, the minimum excess noise figure of the latter cannot be less than that of the former.*

Eq. (42) has established a lower bound for the excess noise figure achievable with lossless imbeddings of an amplifier. Several questions still remain unanswered.

1) Can this lower bound actually be realized with every amplifier?
2) Can this lower bound be achieved with a positive output impedance?
3) What is the best noise figure at large gain achievable by using amplifiers of different types?
4) How is the minimum noise figure at large gain affected by the use of lossy imbedding networks?

VI. GENERALIZATION OF THE NOISE MEASURE FOR 2n-TERMINAL-PAIR NETWORKS

In order to answer the ambitious questions posed at the end of the preceding section we have to make use of a formal generalization of the noise-measure concept to 2n-terminal-pair networks. This generalization is suggested by the matrix notation developed in (29). Charterize the 2n-terminal-pair network of Fig. 7 by the general-circuit equation

$$v = Tu + \delta, \tag{43}$$

where v, u, and δ are all column vectors of 2nth order. The general-circuit matrix T is a square matrix of 2nth order. The column vector u characterizes the voltages and currents at one set of n-terminal pairs regarded as "output," while the column vector v characterizes the voltages and currents at the other set of n-terminal pairs regarded as "input." The choice of the terminal pairs is in general arbitrary, but is often dictated by expediency. Similarly, the order in which the voltages and currents are assigned to the terminal pairs is arbitrary.

The permutation matrix P_n of the 2n-terminal-pair network follows from the requirement that the term $-v^{\dagger}P_n v + u^{\dagger}P_n u$ represents the power generated in the network (see Appendix I). For the particular case of the network illustrated in Fig. 15, the permutation matrix is given in (59) of Appendix I.

We now *define* the generalized noise measure as a formal extension of (29) in terms of an *arbitrary* column vector y of 2nth order:

$$M_e \equiv \frac{y^{\dagger}\overline{\delta\delta^{\dagger}}y}{y^{\dagger}(P_n - TP_nT^{\dagger})y}\left(\frac{1}{2kT\Delta f}\right). \tag{44}$$

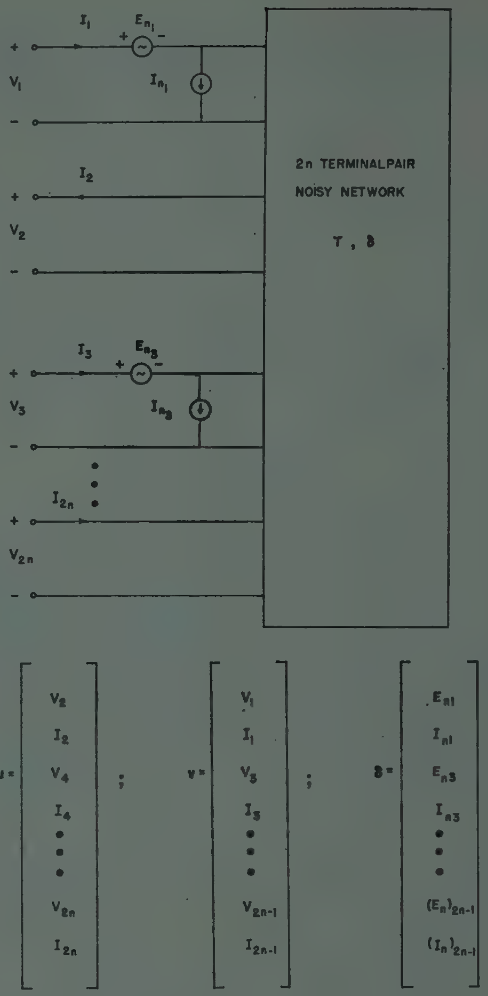
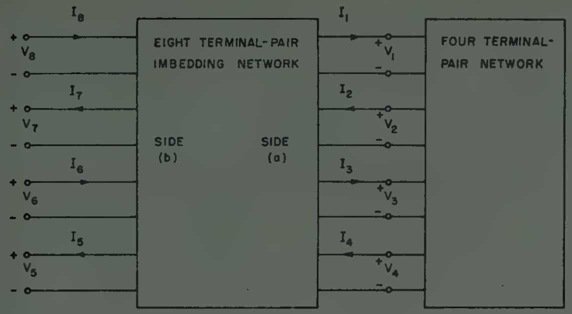

I_1
E_{n_1}
V_1
I_{n_1}
I_2
V_2
2n TERMINALPAIR
NOISY NETWORK
T , δ
I_3
E_{n_3}
V_3
I_{n_3}
I_{2n}
V_{2n}
+
-
u =
V_2 I_2 V_4 I_4 V_{2n} I_{2n}
v =
V_1 I_1 V_3 I_3 V_{2n-1} I_{2n-1}
δ =
E_{n1} I_{n1} E_{n3} I_{n3} $(E_n)_{2n-1}$ $(I_n)_{2n-1}$

Fig. 7—2n-terminal-pair noisy network.

We may study again the change of the value of M_e when the 2n-terminal-pair network is subjected to a lossless transformation. By virtue of the matrix formalism used in Section V, the findings of that section can be generalized immediately to a 2n-terminal-pair network (see Fig. 8). If the general-circuit matrix T of the 4n-terminal-pair imbedding network is split into an array of four matrices of 2nth order, the transformation between the various voltages and currents at input and output of the 4n-terminal-pair network can be written

$$\begin{aligned} v_a &= T_{aa}u_a + T_{ab}u_b \\ v_b &= T_{ba}u_a + T_{bb}u_b. \end{aligned} \tag{45}$$

Fig. 8 serves as an illustration of the way in which the excitation vectors v and u can be split into subvectors v_a, v_b, u_a, and u_b. Applying transformation (45) to the noise measure (44), and using the requirement of losslessness for the imbedding network, (64), we find that the value of M_e after the transformation is


EIGHT TERMINAL-PAIR IMBEDDING NETWORK
FOUR TERMINAL-PAIR NETWORK
SIDE (b)
SIDE (a)
I_8
V_8
I_7
V_7
I_6
V_6
I_5
V_5
I_1
V_1
I_2
V_2
I_3
V_3
I_4
V_4

$$u = \begin{bmatrix} V_1 \\ I_1 \\ V_3 \\ I_3 \\ --- \\ V_5 \\ I_5 \\ V_7 \\ I_7 \end{bmatrix} = \begin{bmatrix} u_a \\ --- \\ u_b \end{bmatrix}; \qquad v = \begin{bmatrix} V_2 \\ I_2 \\ V_4 \\ I_4 \\ --- \\ V_6 \\ I_6 \\ V_8 \\ I_8 \end{bmatrix} = \begin{bmatrix} v_a \\ --- \\ v_b \end{bmatrix}$$

Fig. 8—Imbedding of a four-terminal-pair network. Column vectors *u* and *v* represent "output" and "inputs" with reference to the eight-terminal-pair imbedding network.

$$M_e' = \frac{y^\dagger Q\overline{\delta\delta^\dagger}Q^\dagger y}{y^\dagger Q(P_n - TP_nT^\dagger)Q^\dagger y}\left(\frac{1}{2kT\Delta f}\right). \tag{46}$$

[Compare with (36)–(40) for the two-terminal-pair network.]

It is shown in Appendix II that a quantity of the form of (46) has $2n$ values which are stationary with regard to arbitrary changes of the matrix Q. These values are again proportional, by the factor $kT\Delta f$, to the eigenvalues of the characteristic noise matrix,

$$N = \tfrac{1}{2}(P_n - TP_nT^\dagger)^{-1}\overline{\delta\delta^\dagger}, \tag{47}$$

which are invariant to a lossless transformation. Again we must distinguish three cases, according to the character of $P_n - TP_nT^\dagger$. The distribution of eigenvalues for each case is shown in Fig. 9. Once more, in case 3 the forbidden range of M_e' between positive and negative extrema arises because (46) reverses sign only when the denominator passes through zero.

VII. Arbitrary Lossless Interconnection of Amplifiers

The foregoing results can now be applied to the proof of the following theorem.

Theorem 2

Consider a general lossless interconnection of an arbitrary number of different and independently noisy two-terminal-pair amplifiers that results in a two-terminal-pair network with an available gain, G, greater than one. When the amplifier is driven from a source that has an internal impedance with positive real part, the noise measure of the resulting two-terminal-pair network cannot be less than the optimum noise measure of the best amplifier; i.e., the amplifier with the least positive eigenvalue of its characteristic noise matrix.

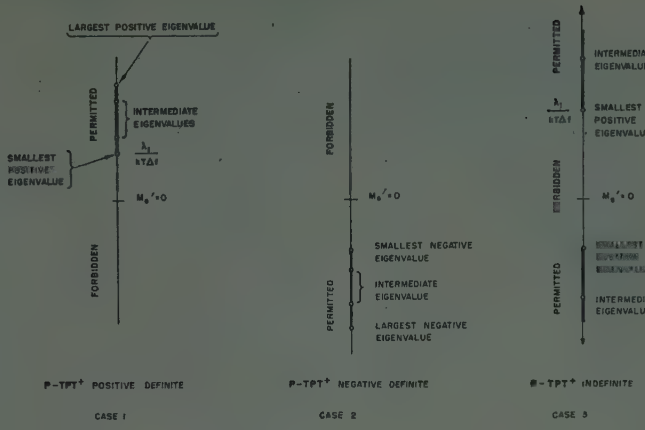

LARGEST POSITIVE EIGENVALUE
PERMITTED
INTERMEDIATE EIGENVALUES
SMALLEST POSITIVE EIGENVALUE
$\frac{\lambda_1}{kT\Delta f}$
$M_e'=0$
FORBIDDEN
P-TPT+ POSITIVE DEFINITE
CASE 1
FORBIDDEN
$M_e'=0$
SMALLEST NEGATIVE EIGENVALUE
INTERMEDIATE EIGENVALUE
PERMITTED
LARGEST NEGATIVE EIGENVALUE
P-TPT+ NEGATIVE DEFINITE
CASE 2
PERMITTED
INTERMEDIATE EIGENVALUE
$\frac{\lambda_1}{kT\Delta f}$
SMALLEST POSITIVE EIGENVALUE
FORBIDDEN
$M_e'=0$
SMALLEST NEGATIVE EIGENVALUE
PERMITTED
INTERMEDIATE EIGENVALUE
P-TPT+ INDEFINITE
CASE 3

Fig. 9—Schematic of permitted values of M_e' for four-terminal-pair networks.

Let us turn to the n two-terminal-pair networks of Fig. 10. They have the general circuit matrices $T_{(i)}$ and the noise column vectors $\boldsymbol{\delta}_{(i)}$, with i going from 1 to n. The networks can be arranged in an array so as to form a $2n$-terminal-pair network. The resulting $2n$-terminal-pair network has a T matrix which consists of a diagonal array of the individual $T_{(i)}$

$$T = \operatorname{diag}\,(T_{(1)}, T_{(2)}, \cdots, T_{(n)}). \tag{48}$$

If the noises in the different amplifiers are *uncorrelated*, the correlation matrix $\overline{\delta\delta^\dagger}$ of the over-all amplifier splits into a diagonal array of correlation matrices of second order of the n amplifiers

$$\overline{\delta\delta^\dagger} = \operatorname{diag}\,(\overline{\delta\delta^\dagger}_{(1)}, \overline{\delta\delta^\dagger}_{(2)}, \cdots, \overline{\delta\delta^\dagger}_{(n)}). \tag{49}$$

Similarly, the matrix $P_n - TP_nT^+$ of the over-all network also splits into a diagonal array of second-order submatrices.

$$P_n - TP_nT^\dagger = \operatorname{diag}\,[(P - T_{(1)}PT^\dagger_{(1)}), \cdots, (P - T_{(n)}PT^\dagger_{(n)})]. \tag{50}$$

Thus, the characteristic noise matrix N of the $2n$-terminal-pair network, on the right-hand side of Fig. 10, a matrix of $2n$th order, splits into a diagonal array of the $N_{(i)}$'s, the characteristic noise matrices of the individual amplifiers,

$$N = \operatorname{diag}\,(N_{(1)}, N_{(2)}, \cdots, N_{(n)}). \tag{51}$$

The eigenvalues of N are identical with the $2n$ eigenvalues of the n noise matrices $N_{(1)}$ to $N_{(n)}$. Thus, if the n two-terminal-pair networks are imbedded in a $4n$-terminal-pair lossless network (which preserves the eigenvalues), a new $2n$-terminal-pair network results that has a characteristic noise matrix with $2n$ eigenvalues that are equal to the eigenvalues of the second-order N matrices of the n amplifiers.

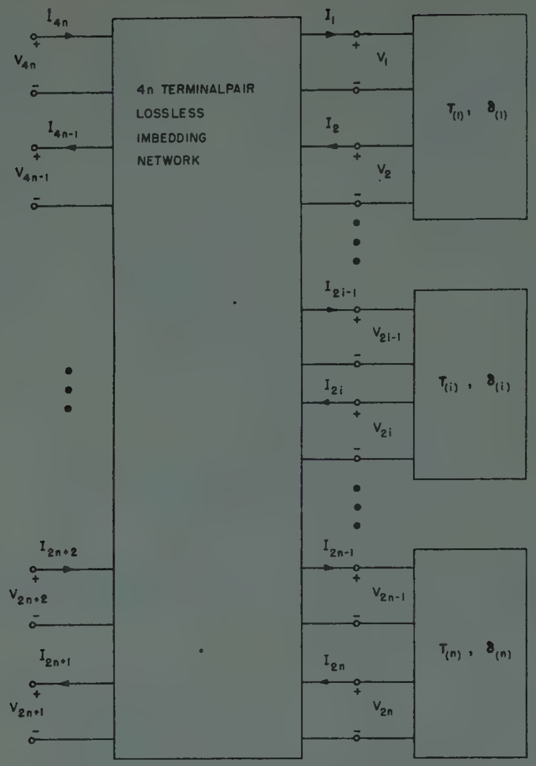


Fig. 10—Lossless interconnection of several amplifiers.

A two-terminal-pair network is obtained from the $2n$-terminal-pair network if all but 2 terminal pairs are open-circuited. This represents the most general (lossless) way in which n networks can be interconnected to form a single two-terminal-pair network. Let the resulting two-terminal-pair network have the circuit matrix $\boldsymbol{T}_r$ and the noise vector $\boldsymbol{\delta}_r$. In Appendix III it is shown that the noise measure $(M_e)_r$ of the resulting network,

$$(M_e)_r = \frac{y_r^\dagger \overline{\delta_r \delta_r^\dagger} y_r}{y_r^\dagger (P - T_r P T_r^\dagger) y_r} \frac{1}{2kT\Delta f}, \tag{52}$$

is a special case of the noise measure M_e of the $2n$-terminal-pair network, as given in (44). $(M_e)_r$ is obtained from M_e by a special choice of the vector $\boldsymbol{y}$ of $2n$th order. This shows that $(M_e)_r$ can vary only within the limits imposed upon M_e. In particular, if the smallest positive eigenvalue among the $2n$ eigenvalues of $\boldsymbol{N}$ is denoted by λ_1, we have, for positive $(M_e)_r$,

$$(M_e)_r \geq \lambda_1/kT\Delta f.$$

But, λ_1 is the optimum noise measure of the best amplifier among the n original amplifiers used. This proves Theorem 2.

VIII. Lossy Imbedding of an Amplifier

Theorem 2 can be extended to the following theorem.

Theorem 3

Passive lossy interconnections of amplifiers cannot lead to a positive noise measure lower than that achievable with lossless interconnections.

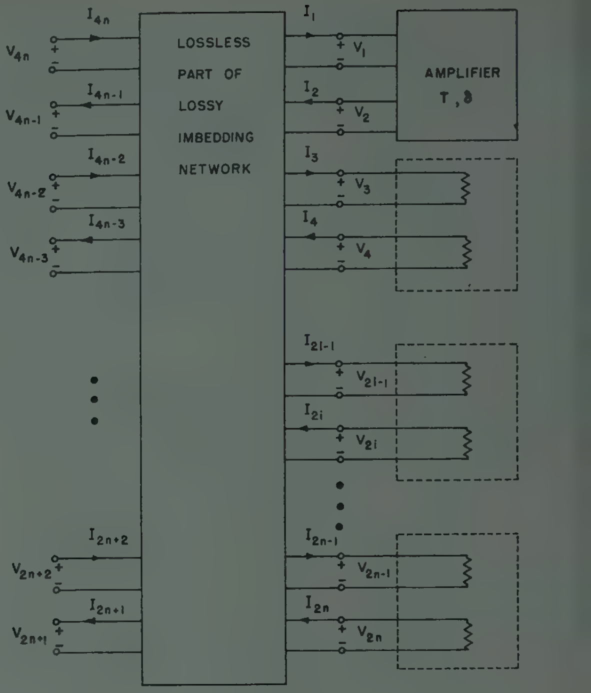


Fig. 11—Lossy imbedding of an amplifier.

Let us suppose first that we have found a lossy reciprocal transformation network for a two-terminal-pair amplifier which yields the lowest positive two-terminal-pair noise measure. Draw out each resisto of the resulting transformation network as a new terminal pair, and assume, for convenience, that there are an even number, $2n-2$, of resistances, which we place on the right-hand side of Fig. 11. Add an equal number o dummy terminal pairs on the left-hand side of the network, thereby creating $2n$ accessible terminal pairs on the left. Denote the original input and output-termina pairs of the transformed amplifier by $4n$ and $4n-1$, respectively. The amplifier and the $2n-2$ resistances on the right-hand side comprise a $2n$-terminal-pair network (similar to Fig. 10) with a characteristic noise matrix with $2n$ eigenvalues. Two of these pertain to the amplifier. The others pertain to two-terminal-pair passive (resistive) networks at equilibrium temperature T.

In Section II we have shown that the noise measure of any passive two-terminal-pair network at therma equilibrium is always -1. Thus, if a given passive two-terminal-pair network at equilibrium temperature T i imbedded in a variable, lossless, four-terminal-pair network, the resulting two-terminal-pair must always have the noise measure $M_e=-1$. Since the range of M_e i limited by the two (negative) eigenvalues of the corresponding characteristic noise matrix, as shown in Fig. 6 case 2, we conclude that *both eigenvalues* must b $-kT\Delta f$.

Referring again to Fig. 11, it follows that both eigenvalues of $N_{(k)}$ for the kth pair of resistances are equal t $-kT\Delta f$. The lossless $4n$-terminal-pair network leave the eigenvalues of $\boldsymbol{N}$ invariant (see Section V). Thus the over-all $2n$-terminal-pair network of Fig. 11 has th same eigenvalues, namely $-kT\Delta f$. The only *positive* eigenvalue(s) is (are) contributed by the amplifier. The positive values of the generalized noise measure, (44), of this $2n$-terminal-pair network have to lie (see Section VI) in the range *above* the least positive eigenvalue $\lambda_1/kT\Delta f$, as shown in Fig. 9. If all dummy terminal pairs $(2n+1)$ to $(4n-2)$ are now open-circuited, we obtain the original transformed two-terminal-pair amplifier with a particular noise measure. This noise measure is, according to Section VII, a special case of the generalized noise measure, (44). Accordingly, its value must lie within the allowed range of the generalized noise measure; hence it cannot be less than $\lambda_1/kT\Delta f$. Thus, the noise measure of the amplifier imbedded in the assumed lossy network cannot have a positive value lower than that which could have been achieved with a lossless imbedding network. This argument remains valid even when the temperature of the lossy imbedding network is lowered so that the eigenvalues of N arising from the resistance networks approach zero ever so closely, because they do so from the negative side.

The above result can be extended to the case in which the transformation network contains an odd number of resistances or, indeed, any passive (possibly nonreciprocal) networks of known noise performance. Use is made of the "canonical" form of such networks, mentioned in Section IX-B, and treated generally in Haus and Adler [6] and Mason [7].

IX. REALIZATION OF THE OPTIMUM NOISE MEASURE

The preceding sections were devoted to the demonstration of the properties of noise measure. In particular, it has been shown that the optimum noise measure of an amplifier determines the lower bound to the excess noise figure at high gain ($G_e \rightarrow \infty$) of a particular type of amplifier. This includes the use of either a single amplifier, or of a passive interconnection of amplifiers of the same type.

It now becomes important to know precisely how, by external network operations upon any given two-terminal-pair amplifier, its minimum positive noise measure can actually be achieved. Unfortunately, space limitations imposed upon this paper have made it necessary to discuss elsewhere [8] the detailed proofs pertinent to this question. Nevertheless, the form of the external networks used to realize optimum noise performance illuminates so much the relationship between the preceding rather abstract general theory and the procedures in current practice, that at least a brief presentation of the results must be included here.

In the realizations which will be presented, the source impedance and the amplifier output impedance (with the source connected) will always have positive real parts. It follows that, by cascading identical optimized amplifiers with appropriate lossless impedance transformation networks, arbitrarily high gain can be achieved at the optimized noise measure, and minimum noise figure at high gain can, thereby, be realized.

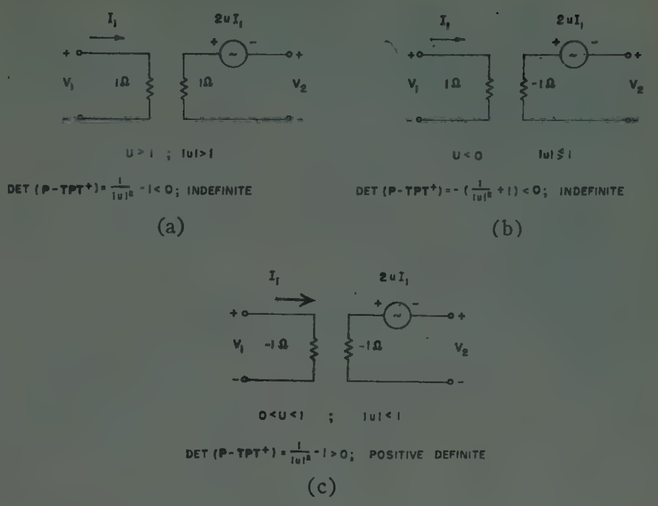

I₁
2uI₁
+
-
V₁
1Ω
1Ω
V₂
U > 1 ; |u|>1
DET (P-TPT⁺) = 1/|u|² - 1 < 0; INDEFINITE
(a)
I₁
2uI₁
V₁
1Ω
-1Ω
V₂
U < 0
|u| ≶ 1
DET (P-TPT⁺) = - (1/|u|² + 1) < 0; INDEFINITE
(b)
I₁
2uI₁
V₁
-1Ω
-1Ω
V₂
0<U<1 ; |u|<1
DET (P-TPT⁺) = 1/|u|² - 1 > 0; POSITIVE DEFINITE
(c)

Fig. 12—Classes of amplifiers.

The noise performance optimization problem is solved conveniently by referring to a more detailed classification of nonpassive two-terminal-pair networks (*i.e.*, amplifiers) than we have used so far. In particular, Mason [7] has shown that every such network can be reduced by lossless *reciprocal* imbedding to one of the three basic types shown in Fig. 12. His classification is based primarily upon the range of values of the *unilateral gain U*

$$U = \frac{|Z_{21} - Z_{12}|^2}{4(R_{11}R_{22} - R_{12}R_{21})} \tag{53}$$

where the R's are the real parts of the impedance matrix elements. Since the numerical value of U is invariant to lossless *reciprocal* transformations [7], none of the three types can be carried into any other by such transformations.

The first type [Fig. 12(a)], with $U>1$, is by far the most common. The majority of vacuum tube and transistor amplifiers belong to this class. The second type [Fig. 12(b)], $U<0$, is less common. It does, however, share one important property with the first; namely both have

$$\det(\boldsymbol{P} - \boldsymbol{TPT}^{\dagger}) < 0 \tag{54a}$$

which means that they can absorb, as well as deliver, power. It is perhaps not surprising, therefore, that with lossless *nonreciprocal* transformations amplifiers of the type of Fig. 12(b) can be carried into the form shown in Fig. 12(a) [8].

The amplifier in Fig. 12(c), however, has

$$\det(\boldsymbol{P} - \boldsymbol{TPT}^{\dagger}) > 0 \tag{54b}$$

and cannot, under any terminal condition, absorb power. Obviously it cannot be reduced to any of the other forms by any *lossless* transformation whatsoever. It is a "negative-resistance" amplifier.

Recalling from (40) and subsequent equations that the optimum noise measure is not changed by any lossless transformation, we conclude that noise performance optimization of amplifiers need only be carried out on networks of the specific forms Fig. 12(a) and Fig. 12(c), and this will be sufficient to cover all nonpassive cases.

A. Optimization of Amplifier with det $(P-TPT^\dagger)<0$

The key point in achieving optimum noise performance of amplifiers obeying condition (54a) is contained in the theorem [8]:

The optimum noise measure of the amplifier of Fig. 12(a) can be achieved with a positive source resistance by using only a suitable lossless reciprocal mismatching network at the input. The output impedance remains 1Ω.

The value of the optimum noise measure is [8]

$$(M_e)_{\text{opt}} = \frac{\lambda_1}{kT\Delta f} = \frac{1}{8kT\Delta f}\left\{\left[\frac{\overline{|E_{n1}|^2}+\overline{|I_{n1}|^2}}{|u|^2-1}+\frac{2|u|^2-1}{|u|^2-1}\,2\,\text{Re}\,\overline{E_{n1}I_{n1}^*}\right]\right.$$

$$\left.+\sqrt{\left[\frac{\overline{|E_{n1}|^2}+\overline{|I_{n1}|^2}}{|u|^2-1}+\frac{2|u|^2-1}{|u|^2-1}\,2\,\text{Re}\,(\overline{E_{n1}I_{n1}^*})\right]^2+16\frac{|u|^2}{|u|^2-1}\left[\overline{|E_{n1}|^2}\;\overline{|I_{n1}|^2}-\overline{|E_{n1}I_{n1}^*|^2}\right]}\right\} \tag{55}$$

which upon cascading of many identical optimized stages becomes the excess noise figure of the cascade at high gain. Observe that (55) checks with standard noise figure theory [1], [5] only if the gain per stage ($|u|^2$) is large. The same is true of the optimum effective source impedance.

Since all two-terminal-pair amplifiers obeying (54a) can be converted to Fig. 12(a) by lossless imbedding, the foregoing theorem is sufficient. The following detailed corollaries [8] are, however, of some obvious practical importance.

1) *Any unilateral amplifier with $U>1$ may be optimized with input mismatch alone.*
2) *A nonunilateral amplifier with $U>1$, which is also stable for all passive source and load impedances, may be optimized with input mismatch alone.*
3) *Any amplifier with $U>1$ may be optimized by first making it unilateral, using lossless reciprocal networks, and subsequently employing input mismatch.*

The word *optimized* means *achieving $(M_e)_{\text{opt}}$ with a source impedance and a resulting output impedance having positive real parts.*

B. Optimization of Negative-Resistance Amplifiers, det $(P-TPT^\dagger)>0$

Two-terminal-pair negative-resistance amplifiers, obeying condition (54b) can always be optimized by lossless *reciprocal* imbedding. This method is rather uninteresting. Another method, actually valid for *all* the amplifier classes, is especially significant in the negative-resistance case. It stems from the theorem [6], [8]:

*By lossless (nonreciprocal) transformation, any n-terminal-pair linear noisy network can be reduced to a "canonic" form of n isolated (positive or negative) resistors, each in series with a noise voltage generator uncorrelated with all the others. Moreover, the exchangeable power from each such isolated source is the negative of one of the n eigenvalues of the characteristic noise matrix **N**.*

The canonic form for a two-terminal-pair amplifier appears in Fig. 13, opposite. Let the smallest positive eigenvalue of N be

$$\lambda_1 = -\frac{\overline{|E_{n1}|^2}}{4R_1} > 0. \tag{55a}$$

Then it can be shown that [8]:

Connecting the terminal pair (E_{n1}, R_1) into a lossless ideal circulator with a positive (1Ω) balancing resistor at temperature T_0, as shown in Fig. 14, achieves the optimum noise measure $(M_e)_{\min}=\lambda_1/kT\Delta f$, with positive source and output impedance.

This is a general optimization result, valid in particular for the negative resistance amplifier class of interest here [*i.e.*, of the type shown in Fig. 12(c)].

Now, one form of maser amplifier (the only form actually built and tested to date) is representable as a one-terminal-pair negative resistance R_1 in series with a noise voltage generator E_{n1} [8], [9], [11]. Consider for a moment that the maser and some arbitrary positive resistor represent the canonic form of a *two*-terminal-pair network. The only *positive* eigenvalue of N for this network is

$$\lambda_1 = \frac{\overline{|E_{n1}|^2}}{4|R_1|} > 0. \tag{55b}$$

It follows as a corollary of the result stated above in connection with Fig. 14 that:

The noise performance of a one-terminal-pair noisy negative resistance (like one form of the maser) is optimized by employing it in one arm of an ideal circulator, as shown in Fig. 14.

The results of Section IX lead directly to the last of our required theorems.

Theorem 4

The minimum noise figure $F_{\min}$ at arbitrarily high gain can be achieved with external passive network operations

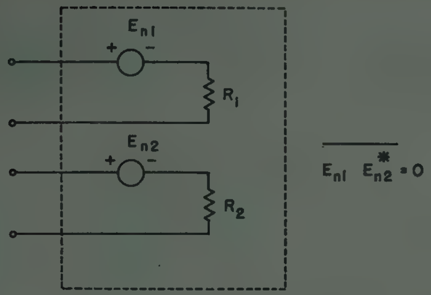


Fig. 13—"Canonic" form of two-terminal-pair amplifier.

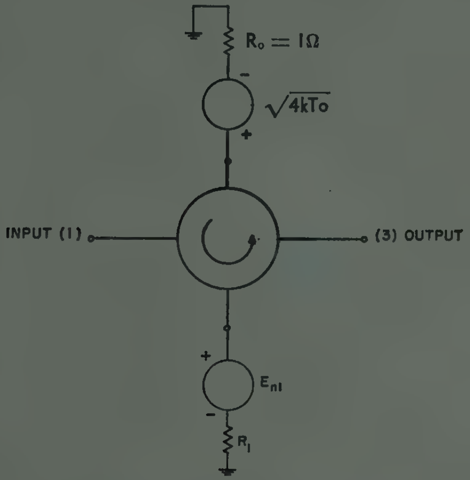


Fig. 14—Realization of optimum amplifier noise performance from "canonic" form of the amplifier.

for all amplifier types, with source and resulting output impedances that have positive real part.

X. Conclusion

Our discussion started from the premise that the (excess) noise figure is a reasonable measure of amplifier noise performance *if* the gain of the amplifier is high. It was natural to suppose at the outset that the quality of an amplifier with regard to noise performance should be measured in terms of the lowest (excess) noise figure at high gain that can be achieved with this amplifier, whether used singly, or in an arbitrary lossless interconnection of amplifiers of the same type. The lowest excess noise figure was found to be equal to the optimum noise measure, a number characteristic of the amplifier alone. The optimum noise measure was then adopted as a measure of amplifier quality (with regard to noise performance). The correctness of this choice was confirmed by the following demonstrations:

1a) The optimum noise measure of any amplifier can actually be achieved with a positive source impedance, positive output impedance, and an available gain $G>1$.

1b) By cascading an arbitrary number of the foregoing optimized amplifiers, an arbitrarily high gain can be achieved with the same noise measure. The excess noise figure, $F-1$, of the resulting cascade is equal to this noise measure.

2) The use of lossy interconnecting networks cannot lead to an excess noise figure at high gain that is lower than that achievable through lossless interconnections.

3) Interconnection of amplifiers of different types cannot lead to an excess noise figure at high gain that is better than that achievable with amplifiers of the "best "class alone. The "best" amplifiers are those with the lowest optimum noise measure.

In a design of a practical system we may either try to actually achieve the lower limit for M_e, or we may use it as a guide to establish the point where further improvement is only achievable with diminishing returns.

This paper thus establishes a limit for the best noise performance achievable with any given amplifier type.

Appendix I

Classification of Source-Free Linear Networks

Consider the linear $2n$-terminal-pair source-free network of Fig. 15 described in terms of an "input" column vector (matrix) $\boldsymbol{v}$ and "output" column vector $\boldsymbol{u}$, and a general-circuit matrix $\boldsymbol{T}$. These matrices are all of order $2n$, and they express the network equations in the form

$$\boldsymbol{v} = \boldsymbol{T}\boldsymbol{u}. \tag{56}$$

We wish to classify the network according to its ability to generate or absorb power.

The net time-average power P flowing *out* of the network (for $n=4$) is

$$\begin{aligned} P = -\tfrac{1}{2}\{ & [V_1I_1^* + V_1^*I_1 + V_3I_3^* + V_3^*I_3 + V_5I_5^* \\ & + V_5^*I_5 + V_7I_7^* + V_7^*I_7] \\ & - [V_2I_2^* + V_2^*I_2 + V_4I_4^* + V_4^*I_4 + V_6I_6^* \\ & + V_6^*I_6 + V_8I_8^* + V_8^*I_8]\}, \end{aligned} \tag{57}$$

which can be written more simply in matrix form as

$$P = \tfrac{1}{2}\{\boldsymbol{u}^\dagger\boldsymbol{P}_4\boldsymbol{u} - \boldsymbol{v}^\dagger\boldsymbol{P}_4\boldsymbol{v}\}, \tag{58}$$

if the "permutation" matrix $\boldsymbol{P}_4$ is given by

$$\boldsymbol{P}_4 = \left(\begin{array}{cc|cc|cc|cc} 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{array}\right), \tag{59}$$

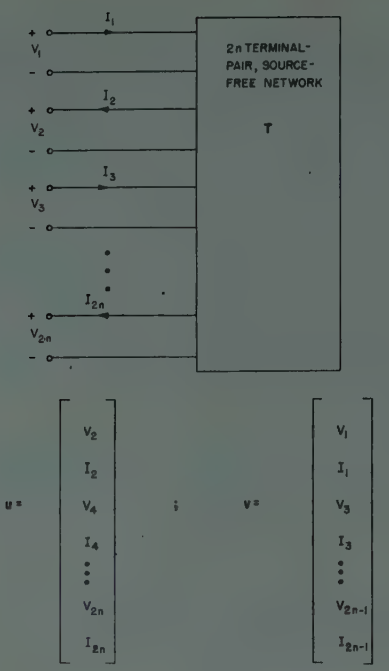

I_1
V_1
I_2
V_2
I_3
V_3
I_{2n}
V_{2n}
2n TERMINAL-PAIR, SOURCE-FREE NETWORK
T
$u = \begin{bmatrix} V_2 \\ I_2 \\ V_4 \\ I_4 \\ \vdots \\ V_{2n} \\ I_{2n} \end{bmatrix}$; $v = \begin{bmatrix} V_1 \\ I_1 \\ V_3 \\ I_3 \\ \vdots \\ V_{2n-1} \\ I_{2n-1} \end{bmatrix}$

Fig. 15—2*n*-terminal-pair source-free network.

which is a logical extension of the matrix defined in (16), and has the same two properties.

The subscript "4" refers to the four square matrices

$$P = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$$

that were defined in (16), and appear along the main diagonal of (59). A $2n$-terminal-pair network with "input" and "output" variables arranged in their column vectors, specifically as shown in Fig. 15, will always have a "permutation" matrix P_n with n P matrices on its diagonal. (Other arrangements of the variables within their respective column matrices lead to different "permutation" matrices, as discussed in Appendix III.)

In view of (56), however, from (58), for a general $2n$-terminal-pair network, we find

$$P = \tfrac{1}{2}u^\dagger\{P_n - T^\dagger P_n T\}u. \tag{60}$$

This leads us to distinguish four cases:

1) The network is passive. It cannot generate any power. Then $P<0$ for all u, and $P_n - T^\dagger P_n T$ is negative definite (or semidefinite).
2) The network is incapable of absorbing power (negative-resistance network); $P>0$ for all u, and $P_n - T^\dagger P_n T$ is positive (semi) definite.
3) The network can either absorb or generate power (most conventional amplifiers are in this class). $P \gtrless 0$ depending upon u, and $P_n - T^\dagger P_n T$ is indefinite.
4) The network is lossless. $P=0$ for all u, and

$$P_n - T^\dagger P_n T = 0. \tag{61}$$

In connection with noise measure, (29), we need a different form of condition (61) for a lossless network. Premultiplying (61) by $P_n(T^\dagger)^{-1}$, and postmultiplying it by $P_nT^\dagger$, we find

$$P_n - TP_nT^\dagger = 0, \tag{62}$$

since $P_n = P_n^{-1}$. For the special four-terminal-pair imbedding network of Fig. 5, we want to express this condition in terms of the partitioned T matrix appearing in (30) and (31). We, therefore, write

$$T = \left[\begin{array}{c|c} T_{aa} & T_{ab} \\ \hline T_{ba} & T_{bb} \end{array}\right]$$

$$P_2 = \left(\begin{array}{cc|cc} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{array}\right) = \left[\begin{array}{c|c} P & 0 \\ \hline 0 & P \end{array}\right] \tag{63}$$

and find four matrix relations of second order:

$$P - T_{aa}PT^\dagger_{aa} - T_{ab}PT^\dagger_{ab} = 0 \tag{64a}$$

$$T_{aa}PT^\dagger_{ba} + T_{ab}PT^\dagger_{bb} = 0 \tag{64b}$$

$$T_{ba}PT^\dagger_{aa} + T_{bb}PT^\dagger_{ab} = 0 \tag{64c}$$

$$P - T_{bb}PT^\dagger_{bb} - T_{ba}PT^\dagger_{ba} = 0. \tag{64d}$$

Eqs. (64b) and (64c) are redundant. This follows directly from them, and the fact that $P = P^\dagger$. Thus, (64) constitutes only three matrix relations among the four matrices T_{aa}, T_{bb}, T_{ab}, T_{ba}.

We shall also need another form of classification (1–3) for networks that are *not* lossless. The desired result is contained in the statement that the matrices

$$P_n - TP_nT^\dagger \quad \text{and} \quad P_n - T^\dagger P_n T \tag{65}$$

have the same definite or semidefinite character. The proof depends directly upon a result obtained by Robinson [11], to which one may appeal directly by converting the matrices in (65) to their forms in terms of the wave-matrix variables by the methods of Appendix III. Therefore, the classification of networks becomes alternatively

1) $P_n - TP_nT^\dagger$ negative (semi) definite (passive),
2) $P_n - TP_nT^\dagger$ positive (semi) definite (negative resistance),
3) $P_n - TP_nT^\dagger$ indefinite (conventional amplifier),
4) $P_n - TP_nT^\dagger$ zero definite (lossless),

and it is in this form that it appears in the noise measure.

APPENDIX II

EXTREMA OF NOISE MEASURE

The search for extrema of the noise measure [(40) and (46)] is equivalent to the study of the extrema of the expression

$$kT\Delta f M_e' = \frac{x^\dagger A x}{x^\dagger B x},$$

under arbitrary variations of the x vector, where

$$Q^\dagger y = x$$

$$\overline{\delta\delta^\dagger} = A$$

$$2(P_n - TP_nT^\dagger) = B.$$

The matrix A is positive (semi) definite, and B is Hermitian. The extrema (or stationary) values of M_e' may be found equivalently as the extrema (or stationary) values of $x^\dagger Bx$, subject to the constraint $x^\dagger Ax = \text{constant}$. Therefore, introduction of the Lagrange multiplier λ^{-1} and recognition that M_e' may be regarded as a function either of the components x_i^* of $x^\dagger$ or of the components x_i of x leads to

$$\frac{\partial}{\partial x_i^*}(x^\dagger Ax - \lambda x^\dagger Bx) = 0; \qquad i = 1, 2, \cdots, n$$

or

$$Ax - \lambda Bx = (A - \lambda B)x = 0. \tag{66}$$

The values of λ are fixed by the requirement

$$\det(A - \lambda B) = 0 = \det(B^{-1}A - \lambda I). \tag{67}$$

The multipliers λ are therefore the eigenvalues of

$$B^{-1}A = \tfrac{1}{2}(P_n - TP_nT^\dagger)^{-1}\overline{\delta\delta^\dagger}. \tag{68}$$

Let λ_s be one of the eigenvalues of $B^{-1}A$ and $x^{(s)}$ the corresponding solution (eigenvector) of (66). Then premultiplication of (66) by $x^{(s)\dagger}$ yields

$$x^{(s)\dagger}Ax^{(s)} = \lambda_s x^{(s)\dagger}Bx^{(s)}$$

or

$$\lambda_s = \frac{x^{(s)\dagger}Ax^{(s)}}{x^{(s)\dagger}Bx^{(s)}} = (M_e')kT\Delta f$$

which is real.

It follows that *the stationary values of the noise measure are the eigenvalues of the matrix* $\frac{1}{2}(P_n - TP_nT^\dagger)^{-1}\overline{\delta\delta^\dagger}$ *divided by* $kT\Delta f$.

APPENDIX III

REARRANGEMENT OF VARIABLES AND REDUCTION TO TWO-TERMINAL-PAIRS

We shall study first how a permutation of the voltages and currents *within* the column matrices v and u of our network description can be taken into account in the analytical formulation of the network equations and the noise measure. Such a permutation obviously does not change the physics of the problem, and therefore should leave the numerical *value* of any physical quantity like power P or noise measure M_e unchanged. It does, however, alter the general algebraic expressions for these quantities in a manner that will be discussed below.

If in a $2n$th-order column vector v we wish to exchange the order of the jth and kth elements v_j and v_k (counted from the top down), we must premultiply it by a $2n$th-order identity matrix in which the jth and kth *rows* have been interchanged. Denote by R_{jk} such a rearranged unit matrix. For example, a sixth-order identity matrix, with rows 3 and 5 interchanged, becomes

$$R_{35} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}. \tag{69}$$

The general rule is that in the identity matrix of appropriate order the jjth (one) and jkth (zero) elements are interchanged, and the kkth (one) and kjth (zero) elements are interchanged. The new column vector v', arising from the exchange of elements v_j and v_k in v, is given by the product

$$v' = R_{jk}v. \tag{70}$$

Thus, if we introduce into our general-circuit matrix description of a noisy network the new "input" vector v' of (70), and a corresponding new "output" vector,

$$u' = R_{jk}u, \tag{71}$$

and observe by inspection that

$$R_{jk}R_{jk} = I, \tag{72}$$

the new network equations become

$$v' = R_{jk}TR_{jk}u' + R_{jk}\delta. \tag{73}$$

Eq. (73) characterizes a "new" network with a noise vector δ' and a general-circuit matrix T' with the property that

$$\delta' = R_{jk}\delta \tag{74a}$$

$$T' = R_{jk}TR_{kj}. \tag{74b}$$

The new form of the "permutation" matrix ${}_pP_n$ for a $2n$-terminal-pair system is found from the power-invariance requirement that, for all v,

$$v^\dagger P_n v = v'^\dagger {}_pP_n v'. \tag{75}$$

Thus, from (70), and from the fact that $R_{jk} = R_{jk}^\dagger$, we find that

$${}_pP_n = R_{jk}P_nR_{jk}. \tag{76}$$

The quantities of interest in the noise measure may now be expressed by using (74) and (76), and the properties of R_{jk}.

$$\overline{\delta'\delta'^\dagger} = R_{jk}\overline{\delta\delta^\dagger}R_{jk} \tag{77a}$$

$${}_pP_n - T'{}_pP_nT'^\dagger = R_{jk}(P_n - TP_nT^\dagger)R_{jk}. \tag{77b}$$

But the noise measure is

$$M_e = \frac{\mathbf{y}^\dagger \overline{\boldsymbol{\delta}\boldsymbol{\delta}^\dagger} \mathbf{y}}{\mathbf{y}^\dagger(\mathbf{P}_n - \mathbf{T}\mathbf{P}_n\mathbf{T}^\dagger)\mathbf{y}}\left(\frac{1}{2kT\Delta f}\right)$$
$$= \frac{(\mathbf{y}^\dagger \mathbf{R}^\dagger{}_{jk})\overline{\boldsymbol{\delta}'\boldsymbol{\delta}'^\dagger}(\mathbf{R}_{jk}\mathbf{y})}{(\mathbf{y}^\dagger \mathbf{R}^\dagger{}_{jk})[{}_p\mathbf{P}_n - \mathbf{T}'{}_p\mathbf{P}_n\mathbf{T}'^\dagger](\mathbf{R}_{jk}\mathbf{y})}\left(\frac{1}{2kT\Delta f}\right), \qquad (78)$$

which shows that if we set

$$\mathbf{y}' = \mathbf{R}_{jk}\mathbf{y}, \qquad (79)$$

the general definition of M_e in (44) can be applied with any rearranged form of the "input" and "output" variables, provided that the appropriate ${}_p\mathbf{P}_n$ is used with the corresponding $\mathbf{T}'$ and $\boldsymbol{\delta}'$.

The extrema of M_e, with respect to lossless imbedding, are obviously unchanged on account of (78). This follows also from the fact that the new characteristic noise matrix $\mathbf{N}'$ is

$$\mathbf{N}' = ({}_p\mathbf{P}_n - \mathbf{T}'{}_p\mathbf{P}_n\mathbf{T}'^\dagger)^{-1}\overline{\boldsymbol{\delta}'\boldsymbol{\delta}'^\dagger} = \mathbf{R}_{jk}{}^{-1}\mathbf{N}\mathbf{R}_{jk}, \quad (80)$$

which is a similarity transformation of $\mathbf{N}$ and has, therefore, the same eigenvalues.

Consider a general $2n$-terminal-pair network with the general-circuit matrix $\mathbf{T}$ and the "noise vector" $\boldsymbol{\delta}$. If all but two terminal pairs of the $2n$-terminal-pair network are left open-circuited, a two-terminal-pair network is effectively obtained. Here we shall show that the noise measure of the resulting two-terminal-pair network is always obtainable from the general $2n$-terminal-pair definition (44) by an appropriate special choice of the column vector $\mathbf{y}$.

The excitation vectors $\mathbf{v}$ and $\mathbf{u}$, which are both of $2n$th order, can be rearranged and subdivided into "input" subvectors $\mathbf{v}_a$, $\mathbf{v}_b'$, and $\mathbf{v}_c'$, and "output" subvectors $\mathbf{u}_a$, $\mathbf{u}_b'$, and $\mathbf{u}_c'$, respectively. The vectors $\mathbf{v}_a$ and $\mathbf{u}_a$ comprise the input and output on the two terminal pairs that are to be retained as the terminals of the resulting two-terminal-pair network terminals 1 and 2 in Fig. 7. The "input" vectors $\mathbf{v}_b'$, $\mathbf{v}_c'$ and the "output" vectors $\mathbf{u}_b'$ and $\mathbf{u}_c'$ are all of $(n-1)$th order and comprise the remaining voltages and currents of Fig. 7 rearranged and separated as follows:

$$\left.\begin{aligned}
&\mathbf{u}_a = \begin{bmatrix} V_2 \\ I_2 \end{bmatrix}; \quad \mathbf{v}_a = \begin{bmatrix} V_1 \\ I_1 \end{bmatrix}; \quad \boldsymbol{\delta}_a = \begin{bmatrix} E_{n1} \\ I_{n1} \end{bmatrix} \\
&\mathbf{u}_b' = \begin{bmatrix} I_4 \\ I_6 \\ I_8 \\ \vdots \\ I_{2n} \end{bmatrix}; \quad \mathbf{v}_b' = \begin{bmatrix} I_3 \\ I_5 \\ I_7 \\ \vdots \\ I_{2n-1} \end{bmatrix}; \quad \boldsymbol{\delta}_b' = \begin{bmatrix} I_{n3} \\ I_{n5} \\ I_{n7} \\ \vdots \\ (I_n)_{2n-1} \end{bmatrix} \\
&\mathbf{u}_c' = \begin{bmatrix} V_4 \\ V_6 \\ V_8 \\ \vdots \\ V_{2n} \end{bmatrix}; \quad \mathbf{v}_c' = \begin{bmatrix} V_3 \\ V_5 \\ V_7 \\ \vdots \\ V_{2n-1} \end{bmatrix}; \quad \boldsymbol{\delta}_c' = \begin{bmatrix} V_{n3} \\ V_{n5} \\ V_{n7} \\ \vdots \\ (V_n)_{2n-1} \end{bmatrix}
\end{aligned}\right\}. \quad (81)$$

The purpose of the rearrangement in (81) is to separate the voltages and currents of the terminal pairs that will be open-circuited. Corresponding to the foregoing rearrangement of the excitation vectors, the network matrix $\mathbf{T}$ and the noise vector $\boldsymbol{\delta}$ must also be rearranged to form $\mathbf{T}'$ and $\boldsymbol{\delta}'$, as shown in (74a) and (74b). The rearranged form $\boldsymbol{\delta}'$ is contained in (81). The rearranged network relations can now be written in the separated form:

$$\begin{aligned}
\mathbf{v}_a &= \mathbf{T}_{aa}\mathbf{u}_a + \mathbf{T}_{ab}'\mathbf{u}_b' + \mathbf{T}_{ac}'\mathbf{u}_c' + \boldsymbol{\delta}_a \\
\mathbf{v}_b' &= \mathbf{T}_{ba}'\mathbf{u}_a + \mathbf{T}_{bb}'\mathbf{u}_b' + \mathbf{T}_{bc}'\mathbf{u}_c' + \boldsymbol{\delta}_b' \\
\mathbf{v}_c' &= \mathbf{T}_{ca}'\mathbf{u}_a + \mathbf{T}_{cb}'\mathbf{u}_b' + \mathbf{T}_{cc}'\mathbf{u}_c' + \boldsymbol{\delta}_c'.
\end{aligned} \qquad (82)$$

The new permutation matrix ${}_p\mathbf{P}_n$ for the rearranged permuted currents and voltages is found from the requirement that the power output P of the network be given by

$$P = -[\mathbf{v}_a{}^\dagger\mathbf{v}_b'{}^\dagger\mathbf{v}_c'{}^\dagger]{}_p\mathbf{P}_n\begin{bmatrix} \mathbf{v}_a \\ \mathbf{v}_b' \\ \mathbf{v}_c' \end{bmatrix} + [\mathbf{u}_a{}^\dagger\mathbf{u}_b'{}^\dagger\mathbf{u}_c'{}^\dagger]{}_p\mathbf{P}_n\begin{bmatrix} \mathbf{u}_a \\ \mathbf{u}_b' \\ \mathbf{u}_c' \end{bmatrix}.$$

By inspection, we confirm that ${}_p\mathbf{P}_n$ is given by

$${}_p\mathbf{P}_n = \left[\begin{array}{c|c|c} \mathbf{P} & 0 & 0 \\ \hline 0 & 0 & I \\ \hline 0 & I & 0 \end{array}\right], \qquad (83)$$

where $\mathbf{P}$ is given by (16) of the text. If we open-circuit all terminal pairs except the two corresponding to $\mathbf{v}_a$ and $\mathbf{u}_a$, we have

$$\mathbf{u}_b' = 0; \qquad \mathbf{v}_b' = 0. \qquad (84)$$

Introducing (84) into (82), we find the equation for the resulting two-terminal-pair network:

$$\mathbf{v}_a = \mathbf{T}_r\mathbf{u}_a + \boldsymbol{\delta}_r \qquad (85)$$

and

$$\begin{aligned}
\mathbf{T}_r &= \mathbf{T}_{aa} - \mathbf{T}_{ac}'\mathbf{T}_{bc}'^{-1}\mathbf{T}_{ba}' \\
\boldsymbol{\delta}_r &= \boldsymbol{\delta}_a - \mathbf{T}_{ac}'\mathbf{T}_{bc}'^{-1}\boldsymbol{\delta}_b'.
\end{aligned} \qquad (86)$$

From (86) we find by matrix multiplication

$$\mathbf{T}_r\mathbf{P}\mathbf{T}_r{}^\dagger = \mathbf{M}\mathbf{T}'{}_p\mathbf{P}_n\mathbf{T}'^\dagger\mathbf{M}^\dagger \qquad (87)$$

and

$$\overline{\boldsymbol{\delta}_r\boldsymbol{\delta}_r{}^\dagger} = \mathbf{M}\overline{\boldsymbol{\delta}'\boldsymbol{\delta}'^\dagger}\mathbf{M}^\dagger$$

where

$$\mathbf{M} = [\mathbf{I} \,\vdots\, -\mathbf{T}_{ac}'\mathbf{T}_{bc}'^{-1} \,\vdots\, \mathbf{0}]. \qquad (88)$$

The noise measure $(M_e)_r$ of the resulting two-terminal-pair network connected to a source with the impedance Z_S [see Section IV, (12) and (29)] is defined by

$$(M_e)_r = \frac{\mathbf{x}^\dagger\overline{\boldsymbol{\delta}_r\boldsymbol{\delta}_r{}^\dagger}\mathbf{x}}{\mathbf{x}^\dagger[\mathbf{P} - \mathbf{T}_r\mathbf{P}\mathbf{T}_r{}^\dagger]\mathbf{x}}\left(\frac{1}{2kT\Delta f}\right) \qquad (89)$$

with

$$\mathbf{x} = \begin{bmatrix} 1 \\ Z_S^* \end{bmatrix}.$$

With the aid of (87) and (88), we can write $(M_e)_r$ in the form

$$(M_e)_r = \frac{(\mathbf{x}^\dagger M)\overline{\delta'\delta'^\dagger}(M^\dagger \mathbf{x})}{(\mathbf{x}^\dagger M)({}_pP_n - T'{}_pP_nT'^\dagger)(M^\dagger \mathbf{x})}\left(\frac{1}{2kT\Delta f}\right). \qquad (90)$$

In (90) we have used the fact that

$$P = M_pP_nM^\dagger,$$

as can be easily checked from (83) and (88). Comparison of (90) with (78) and (44) shows that the noise measure $(M_e)_r$ is indeed a special case of the general noise measure definition, (44), corresponding to the particular choice of y,

$$y = M^\dagger \mathbf{x}. \qquad (91)$$

That is what we set out to prove.

ACKNOWLEDGMENT

The authors are especially grateful to Prof. L. N. Howard, of the Department of Mathematics, M.I.T., who made possible for them the matrix eigenvalue formulation of the problem. They are also indebted to D. L. Bobroff, of Raytheon Manufacturing Company, who noticed in their early results a possible connection with available power.

BIBLIOGRAPHY

[1] van der Ziel, A. *Noise*, New York: Prentice-Hall, 1954.
[2] Haus, H. A. and Adler, R. B. "Invariants of Linear Networks," 1956 IRE CONVENTION RECORD, pt. 2, pp. 53–67.
[3] Haus, H. A., and Adler, R. B. "Limitations on Noise Performance of Linear Amplifiers," paper presented at the Congres International Tubes Hyperfrequences, Paris, June, 1956; to be published in *L'Onde Electrique*.
[4] Haus, H. A., and Adler, R. B. "An Extension of the Noise Figure Definition," PROCEEDINGS OF THE IRE, Vol. 45 (May, 1957), pp. 690–691.
[5] Rothe, H., and Dahlke, W. "Theory of Noisy Four-Poles," PROCEEDINGS OF THE IRE, Vol. 44 (June, 1956), pp. 811–817.
[6] Haus, H. A., and Adler, R. B. "Canonic Form of Linear Noisy Networks," submitted for publication to IRE TRANSACTIONS ON CIRCUIT THEORY.
[7] Mason, S. J., "Power Gain in Feedback Amplifiers," Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Mass., Technical Report 257, August 25, 1953.
[8] Adler, R. B., and Haus, H. A. "Network Realization of Optimum Amplifier Noise Performance," submitted for publication to IRE TRANSACTIONS ON CIRCUIT THEORY.
[9] Wittke, J. P. "Molecular Amplification and Generation of Microwaves," PROCEEDINGS OF THE IRE, Vol. 45 (March, 1957), pp. 291–316.
[10] Muller, M. W., "Noise in a Molecular Amplifier," *Physical Review*, Vol. 106 (April 1, 1957), pp. 8–12.
[11] Robinson, F. N. H., and Haus, H. A. "Analysis of Noise in Electron Beams," *Journal of Electronics*, Vol. 4 (January, 1956), pp. 373–384.

CORRECTION

G. Bemski, author of "Recombination in Semiconductors," which appeared on pages 990–1004 of the June, 1958 issue of PROCEEDINGS, has informed the editors that Figs. 4–6, on pages 995 and 998, were incorrectly numbered. The two figures on page 995 should be Fig. 6 and Fig. 4 instead of Fig. 4 and Fig. 5, and the graph on page 998 should be Fig. 5.

Also, on page 998, on the sixth line of the second paragraph, the word "copper" should be "nickel."

Correspondence

Observations of the U. S. Satellites Explorers I and III by CW Reflection*

The detection of Sputniks I and II by CW reflection at The Ohio State University Radio Observatory has been reported.[1-3] The purpose of this communication is to report that numerous observations have also been made of the U. S. satellites Explorers I and III using the same CW reflection method. In connection with these observations, it is of particular interest that on many occasions the Explorers were detected at heights of the order of 1000 miles. In our earlier Sputnik observations, the satellites were always at heights of less than 500 miles. In order to observe the CW reflections, ionized regions of considerable area are required and, accordingly, the Explorer observations provide evidence of significant ion density occurring at heights of the order of 1000 miles.

The CW reflections were observed by recording 20- or 25-mc signals from WWV. Simultaneous recordings were made on 108 mc of the transmissions from the Explorers. By comparing the WWV and 108-mc records it was noted that numerous WWV bursts occurred during the passages of the Explorers. For example, Fig. 1 shows two recordings taken simultaneously on March 11, 1958. The upper trace is the 20-mc record with deflections due to momentary bursts of WWV signal and the lower trace is the 108-mc record. Between 0539 and 0548 there is a deflection on the 108-mc record due to the signals of Explorer I. At 0543 and 0544 on the 20-mc record, there are small signal bursts of 15 to 30 seconds duration followed at about 0545 by a very large deflection which ended abruptly about 12 seconds later when WWV went off the air for its hourly 4-minute silent period. This signal burst is the largest obtained in weeks of recording and is several times the daytime level of WWV. It is probable that this burst and also the smaller ones at 0543 and 0544 were caused by reflection of WWV signals from ionization produced by Explorer I. At this time Explorer I was believed to be at a height of only a few hundred miles.

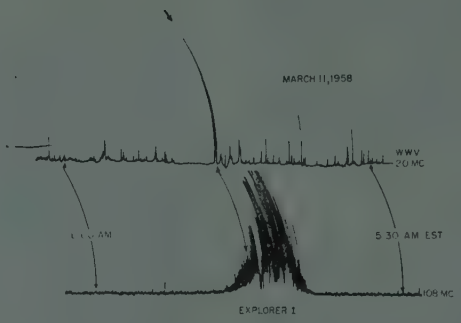


Fig. 1—Simultaneous recordings on March 11, 1958 of Explorer I transmissions on 108-mc (lower) and 20-mc signals from WWV (upper) with large burst of WWV signal occurring during passage of Explorer I. Time is indicated on both traces at 5:30 and 6:00 A.M. by the curved lines which coincide with the curved coordinates of the recorder.

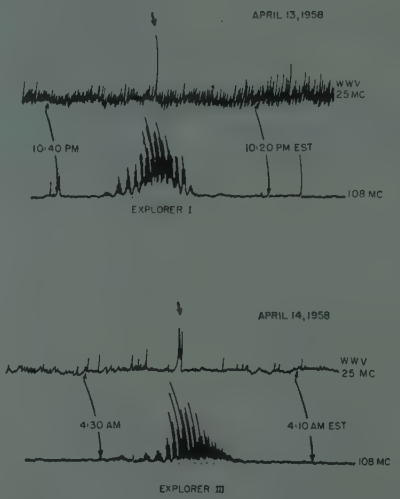


Fig. 2—Recordings of Explorer I and III 108-mc transmissions on the night of April 13–14, 1958, with simultaneous records of 25-mc WWV signals. In both cases bursts of WWV signal, as indicated by the arrows, occur within less than one minute of the meridian transit of the Explorer satellite.

Evidence of WWV reflections from greater heights is presented by the sample records of Fig. 2. The upper pair of traces show the 25-mc WWV signal and 108-mc Explorer I record taken simultaneously on the evening of April 13, 1958; the lower pair show the 25-mc WWV signal and the 108-mc Explorer III record about 6 hours later on the morning of April 14, 1958. During these observations the 108-mc receiver was connected to a pair of spaced antennas acting as an interferometer, the lobes of the pattern being evident in the records. (Only one antenna of the pair was connected during the record of Fig. 1.) In both examples in Fig. 2 a sizable burst of the WWV signal occurred within one minute of the meridian transit of an Explorer satellite. The time of the signal burst corresponds in each case very closely with the time of nearest approach of the satellite. During the entire night from 9 P.M. April 13 to 5 A.M. April 14, there was only one other significant WWV burst. This occurred at 10:10 P.M. and was presumably associated with Sputnik II. What may have been the same object was reported to have been seen from Denver, Colo., at 10:12 P.M. EST. Accordingly, the probability is very small that the bursts in Fig. 2 are due to a random process. Taking into consideration also the close correlation between Explorer passes and WWV bursts on other nights, the probability of a random process being responsible becomes vanishingly small.

From the interferometer patterns of the 108-mc records, calculations indicate that the Explorers in both cases were at heights of the order of 1000 miles. Although the magnitudes of the WWV signal bursts in these and other Explorer observations are large, the duration in all cases is less than one-half minute. This would seem to indicate that the conditions required for observing a reflection are highly critical.

J. D. Kraus
R. C. Higgy
J. S. Albus
Radio Observatory
Dept. of Elec. Eng.
The Ohio State University
Columbus 10, Ohio

---

* Received by the IRE, May 8, 1958.

[1] J. D. Kraus, "Detection of Sputnik I and II by cw reflection," Proc. IRE, vol. 46, pp. 611–612; March, 1958.

[2] J. D. Kraus, "The last days of Sputnik I," Proc. IRE, vol. 46, pp. 612–614; March, 1958.

[3] J. D. Kraus and E. E. Dreese, "Sputnik I's last days in orbit," submitted for publication to Proc. IRE.

WWV Standard Frequency Transmissions*

Since October 9, 1957, the National Bureau of Standards radio stations WWV and WWVH have been maintained as constant as possible with respect to atomic frequency standards maintained and operated by the Boulder Laboratories, National Bureau of Standards. On October 9, 1957, the U.S.A. Frequency Standard was 1.4 parts in 10^9 high with respect to the frequency derived from the UT 2 second (provisional value) as determined by the U. S. Naval Observatory. The atomic frequency standards remain constant and are known to be constant to 1 part in 10^9 or better. The broadcast frequency can be further corrected with respect to the U.S.A. Frequency Standard as indicated in the table below. This correction is *not* with respect to the current value of frequency based on UT 2. A minus sign indicates that the broadcast frequency was low.

The WWV and WWVH time signals are synchronized; however, they may gradually depart from UT 2 (mean solar time corrected for polar variation and annual fluctuation in the rotation of the earth). Corrections are determined and published by the U. S. Naval Observatory.

WWV and WWVH time signals are maintained in close agreement with UT 2 by making step adjustments in time of precisely plus or minus 20 msec on Wednesdays at 1900 UT when necessary; no step adjustment was made at WWV or WWVH during the month.

---

* Received by the IRE, June 16, 1958.

WWV Frequency†

May, 1958 1500 UT	Parts in 10^9
1	−3.6
2	−3.5
3	−3.3
4	−3.2
5	−3.1
6	−2.9
7	−2.8
8	−2.6
9	−2.5
10	−2.4
11	−2.3
12	−2.2
13	−2.1
14	−2.0
15	−1.8
16	−1.6
17	−1.4
18	−1.2
19	−1.1
20	−1.1
21	−1.1‡
22	−1.2‡
23	−1.4‡
24	−1.6‡
25	−1.8‡
26	−2.2‡
27	−2.5
28	−2.9
29	−3.2‡
30	−3.5
31	−3.6

† WWVH frequency is synchronized with that of WWV.

‡ Decrease in frequency of 0.5×10^{-9} at 1900 UT at WWV.

W. D. George
Radio Standards Lab.
Natl. Bur. of Standards
Boulder, Colo.

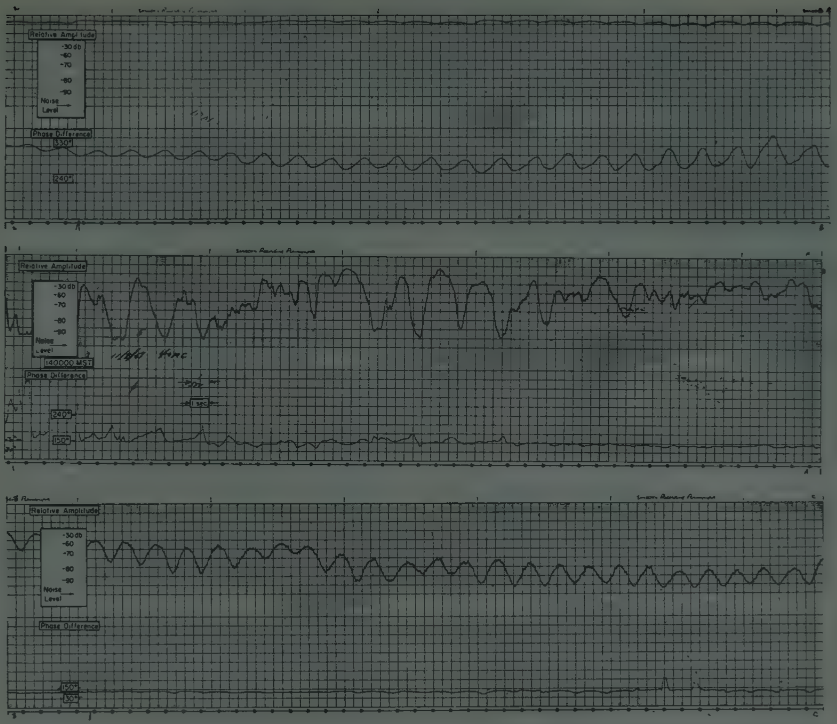


Fig. 1—Sample of relative phase of 40-mc signals received on two antennas spaced 1000 feet (bottom traces on each section) and relative amplitude of signal from one antenna (upper traces). First section represents approximate time of nearest approach, second section, early part of passage (satellite approaching from NW), and third section, approaching end of passage.

Continuous Phase Difference Measurements of Earth Satellites*

Numerous investigations have been made on the two earth satellites successfully launched to date using interferometric techniques of radio astronomy. The Radio Propagation Engineering Division of the National Bureau of Standards, Boulder Laboratories, conducted a series of observations of both satellites using a continuous phase-difference measuring technique developed earlier for studying atmospheric turbulence in the troposphere.[1]

In a conventional interferometer, phase detection is accomplished by vectorial summing before detection. The detector output is thus a function of the amplitude of received signals and the cosine of their relative phase, and only discrete values of output (nulls) are chosen as significant for phase determination.

To remove this limitation on the total usable information in such records, measurements may be made in which the phase detection is performed in a manner which provides essentially constant sensitivity and signal-to-noise ratio.

The general technique used is that described in Herbstreit and Thompson[1] and, in this case, consists of two similar Hammarlund SP-600 receivers operating on 20 (or 40) mc. The local oscillator signals for all three frequency conversions are obtained from one of the receivers to maintain coherence. The phase detection consists of an electronic phasemeter[2] which compares the af tones from the two receivers.

Within the practical limitations of the electronic phasemeters available, the following desirable features are obtained:

1) The output is a linear function of relative phase thus giving constant sensitivity for all phase angles.

2) The phase detector output as a function of signal strength saturates rapidly (at about 1 μv in the system used) and thus may be considered essentially a function of phase only.

3) The phasemeter is capable of detecting phase modulation components as high as the order of 100 cps and thus can respond to the fine structure which undoubtedly exists in the ionosphere.

Consequently, the records of this type contain not only much more information on gross phenomena such as orbit and refraction but also much more in the nature of the fine structure of the received signals.

The instrumentation and its maintenance and calibration are quite straightforward. Samples of records are illustrated in Fig. 1.

The records in general contain information on two types of mechanisms. One is the effect of gross geometrical changes (which account for the lobe structure of the simple interferometer) and the second is the relatively irregular effect of ionospheric turbulence. For considerations of orbit or refraction the former are to be emphasized, while for the study of the latter the geometric effects should be minimized. This choice is made by the orientation of the antenna base line. Since the primary concern for these observations was with turbulence, the base line was chosen to be as feasible as possible, normal to the orbits to be observed. The result is to eliminate largely any "lobe" structure during nearly overhead passes. In the sample record of Fig. 1, the orientation was such that only 5 "lobes" were observed instead of the 80 which would have been expected using a baseline of 40 λ. In addition to the first-order geometrical and turbulence effects noted above, the records many times indicated the presence of a variety of multipath effects. These produced correlated effects (as would be expected) on both phase difference and amplitude (of single signal). That this correlation was not the result of amplitude-phase interaction in the equipment was borne out by visual observations of the Lissajou figure during the recording period. Lack of time has prevented a more thorough analysis of the data to date but the techniques appear to have certain attractive features.

These measurements were the result of a joint effort involving a number of personnel of the Radio Propagation Engineering Division.

J. W. Herbstreit
M. C. Thompson, Jr.
Radio Propagation Engineer Div.
Boulder Laboratories
National Bureau of Standards
Boulder, Colo.

---

* Received by the IRE, January 24, 1958.

[1] J. W. Herbstreit and M. C. Thompson, "Measurements of the phase of radio waves received over transmission paths with electrical lengths varying as a result of atmospheric turbulence," Proc. IRE, vol. 43, pp. 1391–1401; October, 1955.

[2] E. Florman and A. Tait, "An electronic phasemeter," Proc. IRE, vol. 37, pp. 207–210; February, 1949.

Semiconductor *P-N* Junction Radiation Counter*

Semiconductor *p-n* junction diodes that have a reverse breakdown voltage in excess of about 10 volts often exhibit an anomalous region in their reverse current vs voltage characteristic. Such an anomalous region can be readily observed in a current vs voltage display obtained by means of a dynamic tracer.[1] The region is usually located at the onset of avalanche breakdown and is marked by a gap or by multiple traces. On either side of the region the current vs voltage trace is single valued and well defined.

If a diode whose characteristic exhibits such a region is connected in series with a bias voltage and resistance, the values of which are such that the dc load line passes through the anomalous region, pulses will be observed on the voltage vs time display of an oscilloscope connected across the diode or resistance. The times of occurrence of the pulses and their widths are randomly distributed. The pulses are uniformly flat-topped, and have extremely short rise and decay times. With a series resistance of 5000 ohms, the pulse amplitude is typically 0.25 volt.[2]

These pulses have their origin in electrons and holes that are thermally generated within a diffusion length of the depletion layer, or local regions thereof. The thermally-generated carriers that traverse the region of high electric field set up by the bias voltage are multiplied by cumulative collision ionization, in a manner similar to that which takes place in a Geiger counter. The random pulse count rate can be determined by substituting a count-rate meter for the oscilloscope. This thermally-generated count rate, which constitutes a background count, decreases rapidly with temperature,[3] usually as exp $(-W/T)$, where T is the absolute diode temperature and W is the characteristic temperature of the thermal generation process.

When the diode is exposed to visible light, or other sufficiently energetic radiation, additional carriers are generated and the count rate increases. The additional count is found to be proportional to the incident radiation flux, up to extremely high count rates. The device is thus a true radiation detector and counter. Because of the relatively large amplitude flat-topped pulses that are obtained, it differs from conductivity-pulse crystal counters and from semiconductor diode counters previously reported[4,5] in much the same way as a Geiger counter differs from an ionization chamber or from a proportional counter.

Our work was initially devoted to verifying that the device is indeed capable of detecting and counting radiation. Such verification was obtained by using as incident radiation the photons of visible light, and also beta particles from a 40-microcurie Sr^{90}-Y^{90} metal tab. With the latter source we found it necessary to operate the diode at reduced temperature to decrease its thermal background count. Our first successful experiment in detecting and counting betas from this source used a Hughes type 6008 diode operated at about 230 volts and −78 degrees C. In later experiments we have detected and counted betas from the same source with commercial diodes at lower voltages and higher temperatures. For example, we have detected and counted betas with a Hoffman type IN209 diode operated at about 60 volts and 0 degrees C. We believe that diodes can be made to detect and count radiation from weaker sources at room temperature, or higher, and with lower bias voltage.

The work described above was begun by K. Bewig and B. Salzberg at Naval Research Laboratory, and continued later under present auspices. We wish to thank Mr. Bewig for his participation in the early work. In connection with the more recent work we wish to acknowledge the beneficial comments of Drs. E. G. Fubini and K. C. Speh, and the experimental help of Dr. M. J. Zucker.

B. Salzberg
K. Siegel
Airborne Instruments Lab., Inc.
Mineola, N. Y.

---

* Received by the IRE, April 23, 1958.

[1] G. L. Pearson and B. Sawyer, "Silicon *p-n* junction alloy diodes," Proc. IRE, vol. 40, pp. 1348–1351; November, 1952.

[2] K. G. McKay, "Avalanche breakdown in silicon," *Phys. Rev.*, vol. 94, pp. 877–884; May, 1954.

[3] J. E. Scobey, W. A. White, and B. Salzberg, "Fast switching with junction diodes," Proc. IRE, vol. 44, pp. 1880–1881; December, 1956.

[4] K. G. McKay, "A germanium counter," *Phys. Rev.*, vol. 76, pp. 1537–1538; November, 1949.

[5] C. Orman, H. Y. Fan, G. J. Goldsmith, and K. Lark-Horowitz, "Germanium p-n barriers as counters," *Phys. Rev.*, vol. 78, pp. 646–647; June, 1950.

Observed Bunched Electron Current in a Velocity-Modulated Beam*

Space charge bunching problems of velocity-modulated electron beams occupy the attention of many research workers. In experimental studies of velocity-modulated beams, there are two kinds of useful microwave oscillography techniques. One of these is VonFoerster's uhf beam analyzer,[1] and the other is the traveling-wave cathode-ray oscilloscope. Using a beam analyzer, VonFoerster and his coworkers at Illinois University, succeeded in showing a picture of velocity distribution of the bunched electrons at a given point of interest along the beam. On the other hand, several kinds of traveling-wave cathode-ray-tubes (tw crt), which are suitable for recording uhf waveforms or high-speed transients, have already been developed. The author studied fundamental properties of the traveling-wave electron deflection system[2] and tried to utilize the tw crt for the waveform observation of the vhf electron current. In an experimental study of long beam, some typical waveforms of the bunched electron current in a velocity-modulated beam were directly obtained for the first time by oscillograms. They have only been estimated by the electron ballistic theory, and have not been found in an oscillogram.

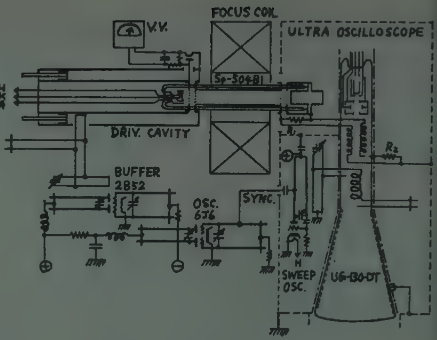


Fig. 1—Circuit diagram for the waveform observation of the bunched electron current in a velocity-modulated tube.

As shown in Fig. 1, an observing apparatus, named the Ultra Oscilloscope, utilized the tw crt (UG-130-DT) and a sinusoidal horizontal sweep oscillator synchronously locked to the external signal. The tw crt has parallel cylindrical helices as the vertical deflecting line, and its frequency response of phase velocity (2.5×10^7 meters per second) is flat up to about 1500 mc. The axial length of the vertical deflecting line is 50 mm, and the phase shift angle on the line is about 1.3 radian at 100 mc, so that the observed distortion by end reflection is negligible. The experimental velocity-modulated tube (Sp-504B1) was designed by scaling for low-frequency and low-voltage operation. A vacuum-tube voltmeter was attached near the input gap for the purpose of indicating the gap voltage which derives the bunching parameter at operation. Connecting the fourth grid to the collector and loading the output gap with the resistance R_1, made from graphite film, the bunched electron current flowing in R_1 is introduced to the vertical deflecting line of the tw crt.

Fig. 2 shows photographs of typical waveforms of the bunched electron current corresponding to the several values of the bunching parameter X. X is equal to $(\omega l_0 K/v_0)$ where $K = V_1/2V_0$, l_0 is the drift-tube length, v_0 is the beam velocity, V_0 is the accerelating voltage and V_1 is the buncher's gap voltage. Fig. 2(a) is for $X = 0.67$, where the electron bunching is considerable, but the electrical angle of the bunched current in a cycle is not so narrow. In Fig. 2(b), where $X = 1.14$ (condition for optimum bunching), it is found that many of the electrons are sharply focused into a small angle range of about 60°. Fig. 2(c), which corresponds to $X = 1.4$, shows a condition of overbunching, where the waveform is double-humped. The photograph clearly shows that in the small-signal operation of the velocity modulation the electron bunching effect is sinusoidal, and the electron wave theory is appropriately applicable. But in the large signal operation (cases for optimum and overbunching), the bunched electron current contains comparatively many har-

---

* Received by the IRE, March 6, 1958.

[1] L. R. Bloom and H. M. Von Foerster, "Ultra-high frequency beam analyzer," *Rev. Sci. Instr.*, vol. 25, pp. 649–653; July, 1954.

[2] H. Maeda and K. Miyaji, "Electron deflection system of traveling-wave cathode-ray tubes," presented at Congress on Tube Hyper-frequencies, Paris, France; May, 1956; *Le Vide*, No. 67; pp. 128–140; January–February, 1957.

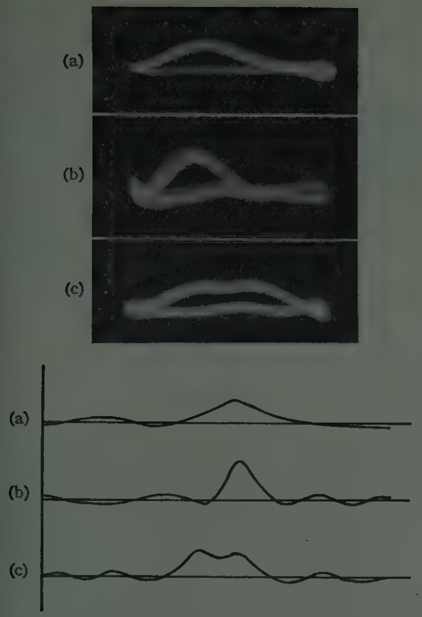


Fig. 2—Observed waveforms of the bunched electron current corresponding to the several values of the bunching parameter X. (a) $X=0.67$, $V_0=500$v, $K=0.14$, $I_0=15$ ma, (b) $X=1.14$, $V_0=500$v, $K=0.4$, $I_0=18$ ma, (c) $X=1.4$, $V_0=500$v, $K=0.29$, $I_0=18$ ma, where I_0 is the beam current.

monic components, where the electron ballistic phenomena seem to be predominant, as shown by the beam analyzer. The oscillograms shown here will introduce further profitable use of the tw crt in experimental study of the operation of other long-beam-tubes.

The author wishes to acknowledge the helpful counsel of Drs. A. Yamashita, H. Kuroda, and K. Miyaji, N.H.K., and the helpful suggestions on the experimental work given by Prof. Y. Koike of To-hoku University, and Dr. K. Owaki of Kobe Kogyo Co.

Haruo Maeda
Japan Broadcasting Corp.
Tokyo, Japan

Design of Transistor Regulated Power Supplies*

The Angle Computer Company, Inc., has done extensive work in the field dealt with by Middlebrook.[1] A super-regulated transistorized power supply, Type 95710, which incorporates to a very great extent many features described by Middlebrook in his article, and which also has some additional new features, has been developed. This power supply was developed for Northrop Aircraft, Inc. early in 1957, with the first production unit being completed in April, 1957.

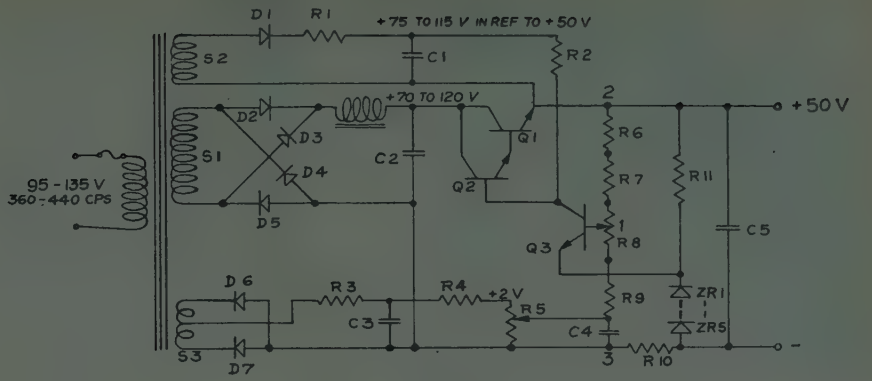


Fig. 1—Schematic diagram.

The basic differences between this power supply and the one described by Middlebrook are as follows:

1) Model 95710 power supply is designated to work at an ambient temperature of up to 100°C, hence silicon transistors are used.

2) Maximum required output current is 50 ma, which at that time was limited also by a shortage in the proper silicon power transistors with higher current capacity.

3) The additional voltage to supply the collector current of Q3 is not regulated.

4) Special compensation of output voltage changes caused by line voltage changes is incorporated.

5) Output voltage changes caused by temperature changes are compensated.

The details and operation of this power supply, in general, will not be discussed because it is basically discussed in detail in Middlebrook's article. I would like only to discuss briefly the compensation of output voltage changes caused by line voltage changes.

Assuming

E_O = output voltage,
E_R = reference voltage on the zener diodes,
E_A = voltage between points 2 and 1,
E_B = voltage between points 1 and 3,

we find the output voltage E_O from

$$E_0 = E_R\left(1 + \frac{E_A}{E_B}\right). \tag{1}$$

Further if

R_B = the resistance between points 1 and 3 formed by part of R_8 and part of R_6 and R_9,
R_A = the resistance formed by rest of R_8, R_7, and R_6,
E_C = unregulated compensating voltage generated on part of R_5 by supply S_3,

the current drawn by the base of Q3 is negligible. We find that

$$\frac{E_A}{E_B} = \frac{1}{\dfrac{E_C}{E_0 - E_C}\cdot\dfrac{R_A + R_B}{R_A} + \dfrac{R_B}{R_A}}. \tag{2}$$

From (1) and (2)

$$E_0 = E_R\left\{1 + \frac{1}{\dfrac{E_C}{E_0 - E_C}\cdot\dfrac{R_A + R_B}{R_A} + \dfrac{R_B}{R_A}}\right\}. \tag{3}$$

From (3) we see that E_O will decrease if E_C increases. Since E_C is proportional to the line voltage, output voltage change caused by line voltage change can be compensated by proper value of E_C which primarily is determined by the basic regulation degree of the power supply.

The additional low power supply S_3, supplying collector of Q3, has its minus connected to plus output voltage which increases the over-all regulation of the voltage applied to the collector at Q3 in reference to common minus.

The final characteristic of the Model 95710 power supply (average production unit) is as follows:

Input voltage range	95–135 v
Input frequency	400 cps ±10 per cent
Output voltage	50 v adjustable ±5 per cent
Line voltage regulation for ±10 per cent line voltage change	±0.003 per cent (±1.5 mv)
Load regulation	0.006 per cent (3 mv)
Output impedance	0.02 ohm
Ripple	0.02 per cent (10 mv)
Output voltage temperature stability	−0.7 mv (0.0015 per cent) per 1°C.

Line voltage regulation, load regulation, and output impedance can be made positive, zero, or negative by adjusting R_5 and R_{10}.

Temperature influence is compensated by R_6 which is made of copper wire. A little higher value of this resistor would improve thermal stability of the output voltage.

LIST OF COMPONENTS

D1–D5	Silicon rectifier 3DS1, International Rectifier Company
D6–D7	Diode IN298
ZR–ZR5	Zener reference element IN430A, National Semiconductor Co.
R1	1 kohm ½W ±10 per cent carbon
R2	39 kohm ½W ±10 per cent carbon
R3	1 kohm ±10 per cent W.W.
R4	600 ohm ±10 per cent W.W.
R5	500-ohm trimpot
R6	70-ohm temperature compensating resistor made of copper wire
R7	600 ohms ±2 per cent W.W.
R8	500-ohm trimpot
R9	3900 ohms ±2 per cent W.W.
R10	2.5- to 3-ohm W.W. positive feedback resistor (load change compensation)
R11	900 ohms ±2 per cent W.W.
C1, C2, C4	1-μf 200 VDCW
C3	4-μf 6 VDCW tantalum capacitor
C5	80-μf 60 V tantalum capacitor
Q1	970 } Texas Instrument Company, silicon transistors
Q2	953
Q3	951

T. F. Kopaczek
Angle Computer Co., Inc.
Glendale, Calif.

---

* Received by the IRE, January 24, 1958.

[1] R. P. Middlebrook, "Design of transistor regulated power supplies," Proc. IRE, vol. 45, pp. 1502–1509; November, 1957.

Use of Microwave Ferrite Toroids to Eliminate External Magnets and Reduce Switching Power*

In most microwave ferrite devices, the ferrite element must be situated in a strong, constant magnetic field for proper operation. In the traverse field type of device, this magnetic bias is commonly supplied by a heavy electromagnet or permanent magnet which usually dwarfs the microwave structure. If the traverse field ferrite device under consideration is a circulator, then the ports of the circulator between which there is complete transmission or rejection may be rearranged or switched by reversing the biasing magnetic field. There are two rather serious difficulties with this procedure. The first difficulty is the high value of power needed to perform the switching. Uebele[1] estimates this power at 1800 watts for a one-microsecond switching time. The second difficulty is the problem of propagating the pulse through the conducting walls of the waveguide. Since a one-tenth microsecond pulse contains frequencies up to 10 mc, this problem is quite serious in going to higher switching speeds.

To solve the problems mentioned above, the use of microwave ferrite toroids has been proposed in three ferrite devices. Two of these devices have been constructed and experimental verification has been obtained. How ferrite toroids may be used to replace ferrite slabs in two nonreciprocal phase shifters is shown in Fig. 1. In Fig. 1(a) is shown the end view of a rectangular waveguide nonreciprocal phase shifter using two slabs oppositely magnetized[2] by an external magnetic structure, which is not shown. Fig. 1(b) shows how these slabs may be replaced by ferrite toroids. A single wire is shown going through the center of the toroids. It is through this single wire that the switching pulse is passed. The coaxial phase shifter,[3] shown with ferrite slabs in Fig. 1(c) and with ferrite toroids in Fig. 1(d), may be switched by passing the switching pulse through the center conductor. A coupled wave type circulator[4] and its toroid counterpart are shown in Fig. 2.

Besides reducing the switching power and the elimination of the external magnet, there are additional advantages which accrue from the use of toroids. Since the toroid is essentially a magnetic circuit with a zero demagnetizing factor, the magnetizing current through the central wire may be reduced to zero and the flux density in the toroid will remain at the remanence value. If the ferrite material has a reasonably square hysteresis loop, then the remanence value will be close to the saturation value and there will be no need to maintain the magnetizing current. Thus, besides eliminating the external magnet, the magnetizing current may be eliminated.

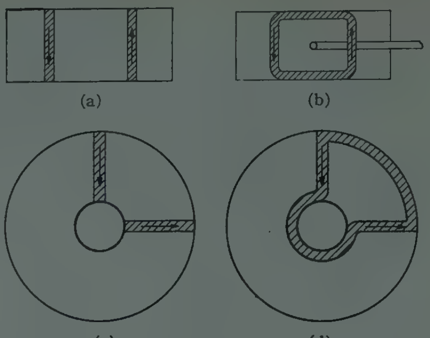

(a) (b)
(c) (d)

Fig. 1

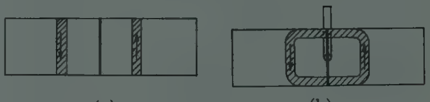

(a) (b)

Fig. 2

Another advantage results in the fact that the two sides of the toroid may be brought much closer together than the two slabs used in the nontoroidal geometries. With an external magnet, as the slabs of ferrite are brought closer together, the *N* and *S* poles of the external magnet approach each other and the flux is shunted directly across the poles with very little going through the ferrites. A toroid may be made very narrow before shunting difficulties arise. The microwave advantages of using narrow toroids result from the fact that in all three cases shown above, more differential phase shift per unit length may be obtained as the slabs approach each other.[2–4] Therefore, shorter waveguide structures will result.

Of the three devices mentioned above, the two rectangular geometries have been constructed and tested with ferrite toroids made in our own laboratory. The construction of the coaxial geometry has been delayed by the odd shape toroids required, which are now in the process of being fabricated by ultrasonic techniques. It was found possible to switch both the rectangular waveguide circulator and the coupled wave circulator in less than one tenth microsecond. The peak power of the switching pulse used was approximately 50 watts. However the ferrite saturates at much lower power. This peak power was required only to get a steep front edge for switching and very probably the power can be considerably reduced when a pulse with a shorter rise time is used.

In another series of experiments the nonreciprocal phase shift in the rectangular phase shifter of Fig. 1(b) was measured with the current on and off. The results indicated in one case that the nonreciprocal phase shift was 40° with the current on and 30° with the current off. This gives what might be called a "microwave squareness factor" of 0.75. No change in the 30° figure was observed even after the toroids were allowed to stand for several days without application of current. This tends to indicate that the remanence value of the flux density in the toroids was retained. Preliminary results, with ferrite material fabricated in our laboratory for this specific application, were very encouraging since they indicated that improvement in the microwave squareness factor was feasible.

The authors wish to acknowledge the support of the Evans Signal Laboratory of the U. S. Army Signal Engineering Laboratores under Contract No. DA-36-039 SC-72327.

M. A. Treuhaft
L. M. Silber
Microwave Res. Inst.
Polytechnic Inst. of Brooklyn
Brooklyn, N. Y.

---

* Received by the IRE, February 28, 1958.

[1] G. S. Uebele, "High-speed ferrite microwave switch," 1957 IRE National Convention Record, pt. 1, pp. 227–234.

[2] B. Lax, K. J. Button, and L. M. Roth, "Ferrite phase shifters in rectangular wave guide," *J. Appl. Phys.*, vol. 25, pp. 1413–1421; November, 1954.

[3] Max Sucher and H. J. Carlin, "Coaxial line nonreciprocal phase shifters," *J. Appl. Phys.*, vol. 38, pp. 921–922; August, 1957.

[4] H. J. Carlin, "Nonreciprocal network theory applied to ferrite microwave devices," *Proc. IEE*, vol. 104, pt. B, supplement no. 6; June, 1957.

A Theorem for Dissipationless Networks*

I believe it is worthwhile mentioning that the theorem of Jones and Cohn[1] concerning insertion loss is a special case of a more general one, and is obtainable in a much simpler and more physical way.

Let us suppose that a dissipationless resistance-terminated network consists of two (not necessarily identical) networks N_a and N_b in tandem (see Fig. 1). According to Thévenin's theorem this can be substituted by the network in Fig. 2 at least as far as the central voltage and current are concerned, where E' is the open-circuit voltage at the terminals 22′. Evidently

$$I = \frac{E'}{Z_1 + Z_2} \tag{1}$$

and the power dissipated by Z_2 is given by:

$$P_2 = |I|^2 \operatorname{Re}(Z_2) = \tfrac{1}{2}|I|^2(Z_2 + Z_2^*) \tag{2}$$

where (*) means conjugation. This power is certainly equal to that dissipated by the termination R_L because this is the only resistive element in Z_2 which can dissipate power.

Now the equivalent generator of Fig. 2 with open-circuit voltage E' and impedance Z_1 is capable of delivering a maximum power which is obtainable if we terminate this generator with the conjugate impedance Z_1^*:

$$P_{1\,\max} = \frac{|E'|^2}{4 \operatorname{Re}(Z_1)} = \frac{|E'|^2}{2(Z_1 + Z_1^*)}. \tag{3}$$

It is easy to prove by elementary methods that this power is the maximum obtainable power which can be furnished by the *original* generator with open-circuit voltage E and impedance R_g. This is due to the fact that if we terminate N_a on terminals 22′ by Z_1^* the generator will see a termination on terminals 11′ exactly equal to R_g. Under these circumstances however, the generator actually delivers the maximum possible power into its termination which can be dissipated only by the real part of Z_1^* which is the only resistance in the network facing the generator.

Finally the inverse square of the modulus of the transfer coefficient is given by the

---

* Received by the IRE, February 14, 1958.

[1] E. M. T. Jones and S. B. Cohn, "Two theorems for dissipationless symmetrical networks," Proc. IRE, vol. 45, p. 1016; July, 1957.

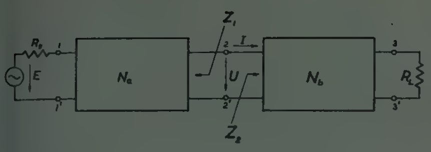


Fig. 1

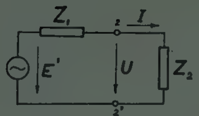


Fig. 2

ratio of these two power expressions, which results after substituting (1) into (2):

$$\frac{1}{|T|^2} = \frac{P_{1\max}}{P_2} = \frac{|Z_1 + Z_2|^2}{(Z_1 + Z_1^*)(Z_2 + Z_2^*)} = 1 + \frac{(R_1 - R_2)^2 + (X_1 + X_2)^2}{4R_1R_2} \qquad (4)$$

if we use the notation $Z_1 = R_1 + jX_1$ and $Z_2 = R_2 + jX_2$. This is the general theorem and a series of known results can be obtained from it in particular cases. The special expressions concerning the symmetrical and antimetrical configurations which have some significance in certain design methods, were known before the cited date of Jones and Cohn[2] and an equation similar to (4) but expressed as a transfer impedance was known as early as 1948.[3]

G. SZENTIRMAI
Standard Telephones and Cables Ltd.
London, Eng.

[2] E. A. Guillemin, "Synthesis of Passive Networks," John Wiley & Sons, Ltd., New York, N. Y. ch. 11, art. 6; 1957.

[3] *Ibid.*, ch. 13, art. 5.

Cutoff Voltage Characteristics of TV Picture Tubes*

The cutoff voltage, *i.e.*, the voltage on the first grid (or cathode) of a crt required for visual extinction of the picture on the screen, represents an important design parameter. The maximally available emission current increases with increasing cutoff voltage while the average transconductance decreases at the same time. The cutoff voltage determines also the maximally required video signal. The "gamma" of the tube is correlated with the cutoff voltage; this correlation is important for achieving a monochromatic gray scale in tricolor picture tubes.[1]

The cutoff voltage for *grid modulation* (the *positive* video signal is applied to the first grid) is given by:[2]

$$V_C = DV_{g2} \qquad (1)$$

with D = penetration factor for the second grid voltage, V_{g2} = second grid voltage (with respect to ground), and where D is expressed by:

$$D = K_1 \frac{Dg_1^3}{dg_1 dg_2} \qquad (2)$$

with

Dg_1 = diameter of the first grid aperture,
dg_1 = spacing between cathode and (outside of) first grid,
dg_2 = spacing between first and second grid,
K_1 = constant.

Note, that (2) is not valid for $dg_1 < \frac{1}{2}Dg_1$ (see below).

The cutoff voltage characteristic for *cathode modulation* (the *negative* video signal is applied to the cathode and the first grid is grounded) can be obtained from (1) by substituting: $V_{g2} \to V_{g2} - V_C$, the potential difference between cathode and second grid in the cutoff point of the current characteristic. We obtain then:[3]

$$V_C = \frac{D}{D+1} V_{g2}. \qquad (3)$$

While (2) expresses proportionality between the cutoff voltage and the penetration factor for grid modulation, (3) states that the cutoff voltage as function of D approaches a finite maximal value with D increasing. This conclusion can be verified easily by forming the first and second derivatives of (3) after D. We obtain:

$$\left.\begin{aligned} \frac{\partial V_C}{\partial D} &= V_{g2} \frac{1}{(1+D)^2} > 0 \\ \frac{\partial^2 V_C}{\partial D^2} &= V_{g2} \frac{1}{(1+D)^3} > 0 \end{aligned}\right\}. \qquad (4)$$

The saturation effect expressed by (4) is of practical importance for tubes having a penetration factor of $\frac{3}{4}$ or larger. Such a high penetration value may be conveniently obtained by decreasing the cathode-first grid spacing ($dg_1 < \frac{1}{2}Dg_1$). As mentioned above, (2) expressing the penetration factor as function of gun design parameters is not valid for $dg_1 < \frac{1}{2}Dg_1$ as an analysis of Klemperer's experimental results indicates.[4] The penetration factor now has to be expressed by:

$$D = K_2 \frac{Dg_1^{5/2}}{dg_1^{3/4} dg_2^{3/4}}. \qquad (5)$$

K_2 is a constant. Substituting (3) into (5) leads to

$$V_C = \frac{K_2 Dg_1^{5/2}}{K_2 Dg_1^{5/2} + dg_1^{3/4} dg_2^{3/4}} V_{g2}. \qquad (6)$$

Eq. (6) states that the cutoff voltage as a function of the cathode-grid spacing shows pronounced saturation with decreasing cathode-grid spacing values. In other words, V_C approaches a finite value for $dg_1 \to 0$ and $Dg_1 \to \infty$.

From the above expression it follows that tubes employing a small cathode-first grid spacing and a high penetration factor are self-regulating on the upper limit of the cutoff voltage range if operated in cathode modulation.

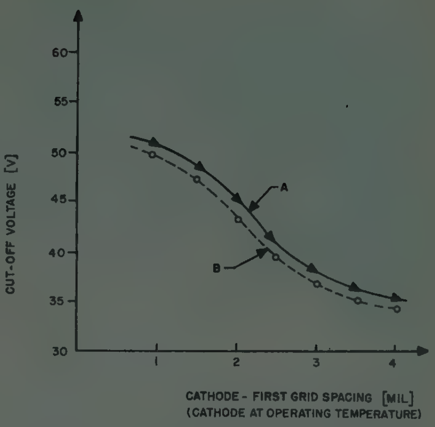


Fig. 1—Cutoff voltage in cathode modulation as function of the cathode-first grid spacing.

The cutoff voltage at constant second grid voltage is depicted as function of the cathode-first grid spacing in Fig. 1. Curve A shows the theoretical results, calculated according to (6) with a numerical value for K_2 determined experimentally for the gun design considered here. Curve B shows the experimental results. It can readily be seen that the cutoff voltage approaches a finite value for the cathode-first grid spacing approaching zero.

W. F. NIKLAS
The Rauland Corp.
Chicago, Ill.

* Received by the IRE, February 24, 1958.

[1] W. F. Niklas, "Some considerations concerning the gamma of tri-color picture tubes," *J. SMPTE*, vol. 65, pp. 546–551; October, 1956.

[2] H. Moss, "The electron gon of the cathode ray tube," *J. Brit. IRE*, vol. 6, pp. 99–124; June, 1946.

[3] W. F. Niklas, C. S. Szegho, and J. Wimpffen, "Fernsehbildrochre fuer Kathodensteuerung mit erhoehter effektiver Perveanz," *Arch. Übertr.*, vol. 12, pp. 54–60; February, 1958.

[4] O. Klemperer, "Electron Optics," Cambridge University Press, Cambridge, Eng., p. 266; 1953.

A Study of Earth Currents Near a VLF Monopole Antenna with a Radial Wire Ground System*

The efficiency of antennas for very low radio frequencies is determined to a large extent by the ohmic losses in the soil near the base of the antenna. It is customary to install a radial wire ground system buried just below the surface of the earth. The purpose of this wire grid is to provide a low-loss return path for the antenna base current in an effort to improve the efficiency of transmission.

The rules for ground system design in the past have been usually empirical and based on the results of experiments on existing installations. The first attempt to design an optimum system was carried out by Abbott.[1] Extensive calculations of the input resistance of a monopole with a radial wire ground system have been carried out by

* Received by the IRE, March 11, 1958.

[1] F. R. Abbott and C. J. Fisher, "Design of Ground System of Radial Conductors for a VLF Transmitter," U. S. Navy Electronics Lab. Rep. No. 105; February 10, 1949.

Wait and Pope.[2,3] It should be emphasized that in this latter work no attempt was made to evaluate the losses associated with high-voltage insulators, tuning coils, and copper losses. The attention was devoted to the ohmic losses in soil and their dependence on number and length of radial wires. Furthermore, the radial wires were assumed to be in intimate contact with the soil being located just below the air-earth interface. The working formula for the component of the input resistance, ΔR, due to ohmic losses in the soil is given by

$$\Delta R \cong \text{real part of } \frac{1}{I_0^2}\int_0^\infty [H_t^\infty]^2 Z(\rho) 2\pi\rho d\rho \quad (1)$$

where I_0 is the base current of the antenna, H_t^∞ is the tangential magnetic field of the antenna assuming a perfectly conducting ground plane, ρ is the distance measured along the ground plane from the base of the antenna, and $Z(\rho)$ is the effective surface impedance of the actual ground plane. $Z(\rho)$ was taken to be equal to the intrinsic impedance of the soil, η, in parallel with the surface impedance of the radial wire grid, Z_s. That is,

$$\begin{aligned} Z(\rho) &= \frac{\eta Z_s}{\eta + Z_s} \quad \text{for } \rho < a \\ &= \eta \quad \text{for } \rho > a \end{aligned} \quad (2)$$

where

$$\eta = \left[\frac{i\mu\omega}{\sigma + i\omega\epsilon}\right]^{1/2} \cong \left[\frac{i\mu\omega}{\sigma}\right]^{1/2}$$

and

$$Z_s = \frac{i\mu\omega d}{2\pi} \ln \frac{d}{2\pi c}$$

where a is the length of the radial wires, μ is the permeability of the ground ($\cong 4\pi \times 10^{-7}$), ω is the angular frequency, σ is the ground conductivity in mhos/meter, ϵ is the dielectric constant of the ground, c is the radius of the radial wires, and d is the spacing between the wires. (If there are N radial wires equally spaced about the base of the antenna, $d \cong 2\pi\rho/N$.)

The validity of (2) for the composite surface impedance was not established in the above mentioned work. The expression used for Z_s, the equivalent shunt impedance for a wire grid, was taken to be the same as that for an infinite parallel wire grid in free space. A recent analysis indicates that the equivalent shunt impedance for an infinite wire grid in the plane interface of two homogeneous media is indeed almost identical to Z_s for the isolated grid if the interwire spacing, d, is always much less than a wavelength in the electrically denser medium.[4] In the present situation, this restriction is equivalent to stating that d should be somewhat less than an electrical skin depth in the soil, that is $d \ll (2/\sigma\mu\omega)^{1/2}$. In most practical cases this condition is met. A question also rises as to the applicability of the formula for surface impedance of a parallel wire grid to a radial wire grid system where the wire spacing is not constant. Furthermore, the wires are not of infinite length being terminated by rods or some other means at a finite distance from the base of the antenna. The assumption that the radial wire behaves locally as a parallel infinite wire grid would seem to be very difficult to justify on purely theoretical grounds. It could be expected, however, that, if the length of the radial wires is large compared to a skin depth in the soil, the wave reflected from the end of the radial wires would be highly attenuated.

As a check of the wire grid theory for antenna ground loss calculations, an experimental test was carried out in Cutler, Me., which is the proposed site of a high-power (1-megw) vlf transmitter for the U. S. Navy. A small test antenna was erected on the site and radial wires were installed in the same manner as in a permanent installation. The actual currents carried by the wires were measured using a small loop pickup placed in proximity to the wires. The average currents carried by the ground were also measured. Now the radio of the total current carried by the wires, I_w, to the current in the soil, I_s, is equal to the ratio of the surface impedance, η, of the soil to the surface impedance, Z_s, of the grid.[2] Therefore, such a test of the splitting of the current between the radial wires and the ground is a good check on the validity of the theory.

Before discussing the experimental results[5] calculations of I_w are presented for pertinent values of the parameters. Denoting the effective antenna height by h, the tangential magnetic field, H_t^∞, on the ground plane at distance ρ from the base is given by

$$H_t^\infty \cong \frac{I_0}{2\pi} \frac{h}{\sqrt{\rho^2 + h^2}}$$

for $\rho \ll$ wavelength. Actually, H_t^∞, is the radial current density in amperes per meter emanating from the antenna for an idealized perfectly conducting ground plane. In the case of the imperfect conducting ground with the radial wire ground system present, the total ground current, I_t, is essentially numerically equal to H_t^∞ and is composed of two parts, I_e, the total earth current and, I_w, the total wire current. We can now write, for purposes of computation,

$$\begin{aligned} X = \left|\frac{I_w}{I_t}\right| &= \left|\frac{1}{1 + \eta/Z_s}\right| \\ &= \frac{\sqrt{2}p}{[p^2 + (p + q)^2]^{1/2}} \end{aligned}$$

where

$$p = 120\pi\delta/\sqrt{2}, \qquad \delta = (\epsilon_0\omega/\sigma)^{1/2}$$

and

$$q = \frac{240\pi^2 P}{N} \ln \frac{P}{NC},$$

$C = c/\lambda$, $P = \rho/\lambda$. The amplitude of the current in one radial wire, i_w, is then given by

$$i_w = \frac{|I_w|}{N} = \frac{I_0}{2\pi N} \frac{h}{\sqrt{\rho^2 + h^2}} X.$$

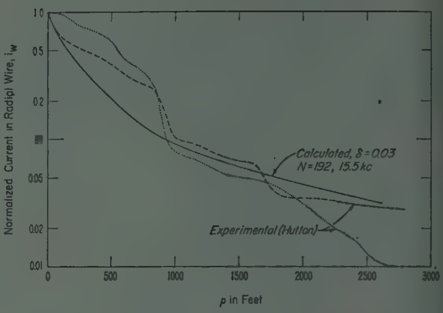


Fig. 1—Decay of current in radial wire as a function of distance ρ from base of antenna.

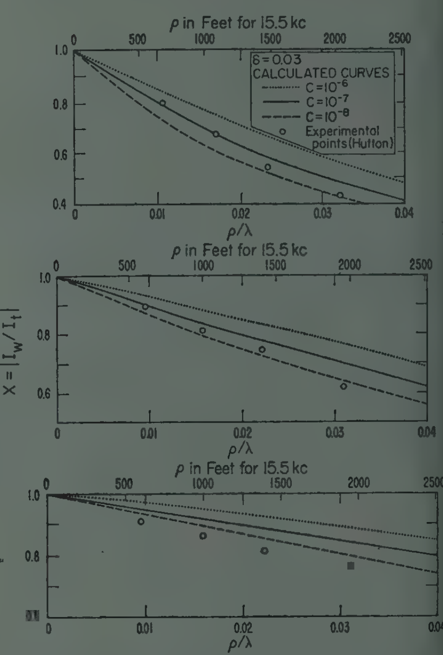


Fig. 2—Comparison of calculated and observed currents in radial wire, for $N = 48$, 96, and 192 reading from top to bottom.

In Fig. 1 the computed current, i_w, normalized to unity at $\rho = 0$, is shown plotted as a function of ρ in feet for $h = 100$ feet, $\lambda = 63{,}400$ feet (15.5 kc), $N = 192$, $\delta = 0.03$ ($\sigma = 1$ milli-mho/meter), $C \cong 10^{-7}$ (no. 8 wire, awg at 15.5 kc). In Fig. 2, computed values of X are shown plotted as a function of ρ/λ for $N = 48$, 96, and 192, respectively. Various values of C are indicated on the curves.

In the experimental setup, the antenna was a monopole with a height of 100 feet with a circular capacity hat with a radius of about 200 feet. In view of the difficulty in clearing land in the heavily wooded and rocky terrain of Maine, it was not feasible to employ many radials emanating in all directions from the antenna. To effect a compromise three radials at azimuth angles of 0°, 180°, and 270° were installed. The sector between about 60° and 100° was then selected as the region for further tests. In case 1, this sector was filled with radials at an angular separation of 7.5°, in case 2 it was 3.75°, and in case 3 it was 1.88°. For these three separations the equivalent value of N would be 48, 96, and 192 respectively.

The indicated points in Fig. 1 are measured current values in two of the central vires of the fan as a function of ρ. The ordiiates are normalized to unity at $\rho=0$. In his case the base current of the antenna vas kept constant at about 1.0 ampere. There is a general agreement with the calcuated curve. Discrepancies could be ascribed o the varying nature of the soil conductivity long the radial wires. Measurements of soil onductivity by the four-probe method indiated a random variation of 50 per cent bout 1.0 milli-mho/meter. The abnormally arge measured values of i_w for the smaller values of ρ in Fig. 1 might be ascribed to the symmetrical variation of the total earth urrent resulting from using a fan of radials ather than a complete array equally spaced or 360°.

---

[2] J. R. Wait and W. A. Pope, "The characteristics of a vertical antenna with a radial conductor ground system," *Appl. Sci. Res.*, *B*, vol. 4, pp. 177–195; 1954.

[3] J. R. Wait and W. A. Pope, "Input resistance of l. f. unipole aerials," *Wireless Eng.*, vol. 32, pp. 131–138; May, 1955.

[4] J. R. Wait, "On the theory of reflection from a wire grid parallel to an interface between homogeneous media," *Appl. Sci. Res.*, *B*, vol. 6, pp. 259–275; 1956.

[5] W. G. Hutton and C. E. Smith, "Navy VLF Site Location Project," Final Rep., Smith Electronics Inc., Cleveland, Ohio; 1957.

A more appealing experiment which vercomes to some extent the asymmetry of the experimental setup is carried out as follows. The receiving coil is moved in a direction transverse to the radial wires at a constant height and constant distance ρ. The measured magnetic field is then essentially constant for the region between the wires and rises to rather pronounced maxima over the wires. The ratio of the maximum field to that between the wires is denoted by B which is given by the relation

$$B \cong \frac{|I_w|/2\pi s}{|I_e|/d}$$

where s is the height of the receiving or pickup coil above the wire and d is their separation. Now, since *the current in the wire lags the current in the ground by 45°*, it follows that[3]

$$\frac{I_w}{I_e} = \frac{2\pi s}{d} B e^{-i\pi/4}$$

or

$$X = \left|\frac{I_w}{I_e + I_w}\right| = \left[\frac{2A^2}{1 + 2A + 2A^2}\right]^{1/2}$$

with

$$A = \frac{\sqrt{2}\pi s}{d} B.$$

Values of X calculated from the experimental data are shown plotted in Fig. 2, for $N=48$, 96, and 192 respectively for $s=4$ feet and $d=2\pi\rho/N$. The agreement between the experimental points and the calculated curve for $C=10^{-7}$ (no. 8 wire at 15.5 kc) is quite good for the two cases of $N=48$ and 96. The departure for the case $N=192$ can be attributed to contribution from the current in the wires to the measured field in the minimal position.

In general, one may say that satisfactory agreement between theory and experiment has been reached. Therefore, further justification is given to the validity of the published calculations of the ground loss component of the base resistance of a monopole with a radial conductor ground system. It should be mentioned, however, that the present study has not considered losses within the aperture or near the base of the antenna. Recent studies by Gustafson, Devaney, and Smith[6] indicate that these losses may be quite large in special antennas for high-power vlf installations.

The author wishes to thank A. D. Watt and T. E. Devaney for helpful advice, C. E. Smith and W. G. Hutton for permission to quote their experimental results, and Anabeth Murphy for assistance with the calculations.

JAMES R. WAIT
Nat. Bur. of Standards
Boulder, Colo.

---

[6] W. E. Gustafson, T. E. Devaney, and A. N. Smith, "Ground System Studies of High Power V.L.F. Antennas," paper no. 38, Record of the VLF Symposium, Boulder, Colo.; January 23–25, 1957.

Design of Video Amplifiers with Stringent Electrical and Mechanical Requirements*

In the special pulse application where high gain, large dynamic range, wide pulses, and fast rise times must be handled simultaneously at low input signal levels, 10 mv or less, prior limiting is not practical. The most applicable circuit, to date, is the inverse feedback pair.[1] However, if, in addition, one wishes to reduce the effects of severe mechanical environment to a minimum, low microphonic tubes must be utilized (Sylvania's new line of ruggedized tubes 6943–44, etc.). However, the g_m of these tubes is notoriously low—about half a nonruggedized tube. Rather than use the standard feedback pair circuit where every other tube is biased, the number of *envelopes* and, consequently, the space and weight, may be reduced by the circuit in Fig. 1 which has a higher average g_m throughout several stages.

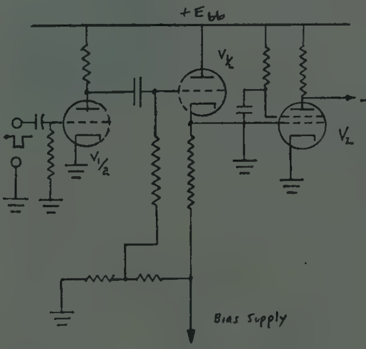


Fig. 1.

By use of this circuit as a basic building block, an amplifier was built which had zero recovery time[2] after a 10-μsec pulse and met the following specifications:

Voltage Gain	3500
Dynamic Range	40 db (voltage)
Pulse Width	1 to 50 μsec
Rise Time + Delay Time	0.08 μsec (10 per cent input to 90 per cent output)
Minimum Signal	10 mvs
Ambient Temperature	−55° C to 71° C

It can be noted that every amplifier tube in the circuit is running at, or near, zero bias, a condition of maximum g_m. The normal coupling capacitors may be balanced with decoupling networks to yield minimum overshoot for pulse widths of concern. The low gain/stage permits use of dual triodes without appreciable Miller effect. The total power consumed in this circuit is less than a feedback pair with the same specifications.

J. A. DEVELET, JR.
The Ramo-Wooldridge Corp.
Los Angeles, Calif.

---

* Received by the IRE, March 24, 1958.

[1] Valley and Wallman, "Vacuum Tube Amplifiers," McGraw-Hill Book Co. Inc., New York, N. Y., M.I.T. Rad. Lab. Ser., vol. 18, p. 134; 1948.

[2] Time to recover original sensitivity after largest signal input.

Networks of Fixed and Variable Resistors*

Recently, Levenstein has discussed the properties of a network of linear rheostats, all fixed to one shaft.[1] These properties, as functions of the shaft rotation, are similar in form to the properties of a network of resistors and inductors as functions of frequency.

It is interesting to apply these ideas to networks of resistors, some of which are fixed while the others have their resistance controllable by some influence other than a shaft rotation. One might have, for instance, a network of fixed resistors and thermistors, the controlling influence being the temperature.[2] Similarly, there might be networks of fixed resistors and of photosensitive resistors, or of fixed resistors and magnetically controlled resistors.[3]

Thus the networks would consist of two types of resistors; one whose resistance was constant, the other having a resistance proportional to some quantity x. For the thermistors, for instance, x would be of the form $x_0 \exp(\phi/kT)$, x_0 and ϕ being constants, k Boltzmann's constant, and T the temperature.[2] For the photoresistors, x would be of the form $x_0 - aI$, a being a constant and I the intensity of illumination, and for the magnetically controlled devices one would expect x of the form $x_0(1+\mu^2B^2)$, μ being the carrier mobility and B the applied magnetic field.[3] All these cases are simpler than that of the rheostats in that there will be no resistance varying as $1-x$. Accordingly, one may adapt Levenstein's first and second propositions directly, p being replaced by x, so that:

1) The driving-point impedance of the network under consideration is a rational function of x, the degree of the numerator being equal to or one more than the degree of the denominator. The zeros and poles are simple, real, and negative, and they alternate. The singularity closest to the origin is a zero.

---

* Received by the IRE, February 20, 1958.

[1] H. Levenstein, "Theory of networks of linearly variable resistances," PROC. IRE, vol. 46, pp. 486–493; February, 1958.

[2] A. van der Ziel, "Solid State Physical Electronics," Prentice-Hall Inc., New York, N. Y., sec. 19.3; 1957.

[3] R. K. Willardson and A. C. Beer, "Magnetoresistance—new tool for electrical control circuits," *Elec Mfg.*, vol. 57, pp. 79–84; January, 1956.

2) The transfer function is a rational function of x, the order of the numerator being equal to or less than that of the denominator. The poles are simple, real, and negative; the zeros may occur anywhere in complex conjugate pairs.

It would be possible to use this theory to obtain, *e.g.*, a prescribed response in measuring devices. Thus, a network approximating the function $(\ln x)^{-1}$, made up of thermistors and resistors, might give a result linear in temperature.

Incidentally, in Levenstein's treatment, elements of resistance proportional to x and to $1-x$ (x being shaft rotation) are involved. An artifice reduces the problem to one in which there is only the variable $p=(1-x)/x$. It is suggested that this is done to avoid the difficulties of dealing with three kinds of element. The writer would suggest that another way of looking at the reason behind the substitution is as follows. The elements of the Z matrix could consist of constant terms, terms proportional to x, and terms proportional to $1-x$. Thus the coefficient of x in any element might be either positive or negative, according to the various values. This is in contrast to the usual network theory of elements which are functions of p, the complex frequency, where the coefficients of p are inherently positive.

Thus, in order to get a theory analogous to that of frequency-dependent elements, one must ensure that the coefficients be positive, and the substitution $(1-x)/x=p$ accomplishes just that.

H. L. Armstrong
Pacific Semiconductors, Inc.
Culver City, Calif.

Space-Charge Grid High-Transconductance Guns*

There are two possible ways of using cathode-ray tubes in transistorized television receivers. In one approach a high enough drive voltage is obtained, in spite of the low supply voltage, by means of special circuitry. In the other approach a high-transconductance gun, *i.e.*, a gun with low-voltage drive requirements, is used. The high-transconductance gun should deliver a (phosphor) screen current of the order of 500 μa at a drive voltage of about 7 volts or less. A brief description is given now of the development which led to a design for a gun satisfying the requirements.

Most of the earlier high-transconductance guns required very close spacings. The resulting resolution was usually inferior to conventional guns. One of the approaches to a high-transconductance gun is to use a space-charge grid.[1,2] The main increase in transconductance results from the movement of a virtual cathode, which serves as the electron source, toward the "anode" as the anode voltage of the "equivalent diode" is increased. The equivalent diode is defined by the virtual cathode and the anode. From Child-Langmuir's Law,

$$i = K\frac{V^{3/2}}{d^2}, \tag{1}$$

one can see that the current increases faster than with the three-half power of the anode voltage since the distance d between the virtual cathode and the anode decreases with increasing anode voltage.

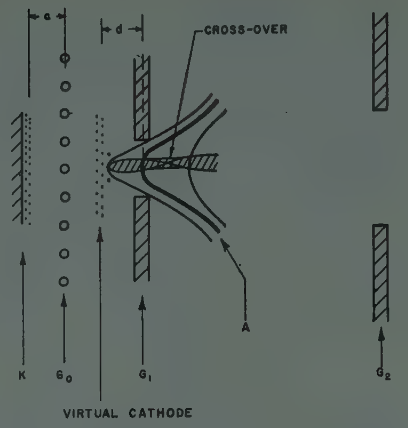


Fig. 1—Current control structure of space-charge grid gun.

The first design studied (Fig. 1) had a wire-mesh space-charge grid G_0 at a constant positive potential. Part of the current is injected through this grid into the space-charge grid (G_0)-control grid (G_1) space. G_1 is formed by an apertured disk. Electrons are drawn out by the accelerating field penetrating through G_1. From available curves,[3] one can see that maximum transconductance can be obtained when the following conditions are satisfied: 1) at maximum (phosphor) screen current $i_{\max}$, *i.e.*, at $V_{G_1}=0$, the space-charge grid voltage V_{G_0} is equal to the potential of equipotential A, penetrating through G_1; and 2) equipotential A is located twice the cathode (K) space-charge grid (G_0) distance a. An increase of transconductance of 69 per cent results. A further increase of transconductance results from the movement of equipotential A during modulation. From an analysis one finds that the maximum possible total increase of transconductance is about 2.2. This result is for the case of equal cutoff voltage in a conventional gun and the space-charge grid gun. It should be kept in mind that the transconductance in a conventional gun increases with decreasing cutoff voltage. The characteristics are shown in Fig. 2. At 14,000-volt screen voltage blooming occurs at about 100 μa screen current and, therefore, the first design does not satisfy present requirements.

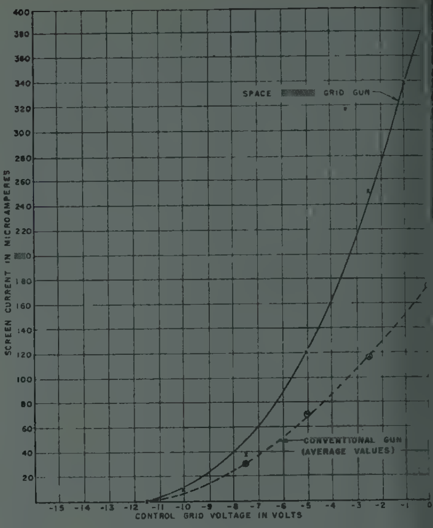


Fig. 2—Characteristic of first design of space-charge grid gun and average characteristic of conventional gun.

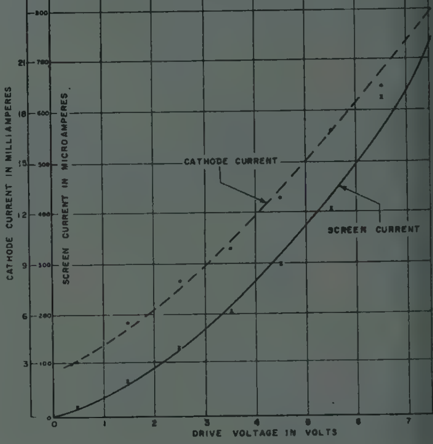


Fig. 3—Characteristics of second design of space-charge grid gun.

The development led to a gun which fully satisfies the set requirements. In this gun the space-charge grid which is at a positive potential is modulated. The phosphor screen current is a function of the supplied current to the virtual cathode as shown in the characteristics of Fig. 3. G_1 has primarily electron-optical functions. For this purpose G_1 is negatively biased. Should one maintain G_1 at a potential close to cathode potential, the virtual cathode could not exist any longer when approaching current cutoff and no proper crossover formation could take place. To minimize the reduction of transconductance by the negative bias at G_1, this grid is modulated simultaneously with G_0 using cathode drive.

The resolution in a 17-inch, 90-degree tube at 14,000 volts was as good as in any conventional tube. Depth of focus was very good. When comparing the performance of such guns with that of conventional guns mounted in identical television sets, it was found that only *about one-tenth drive voltage was required. At 7.5-volt drive voltage a screen current of about 700 μa is obtained.*

Paul H. Gleichauf
General Electric Co.
Syracuse, N. Y

---

* Received by the IRE, March 24, 1958.

[1] G. E. Condliffe, I. Shoenberg, and W. F. Tedham, British Patent No. 431,327.

[2] British Patent No. 525,601.

[3] C. E. Fay, A. L. Samuel, and W. Shockley, "On the theory of space charge between parallel plane electrodes," *Bell Sys. Tech. J.*, vol. 17, pp. 49–79; January, 1938.

Contributors

R. B. Adler

Richard B. Adler (A'44–SM'53) was born in New York, N. Y., on May 9, 1922. He received the B.S. and Sc.D. degrees in electrical engineering from the Massachusetts Institute of Technology, Cambridge in 1943 and 1949, respectively.

During the years 1944 to 1946 he was in the United States Naval Reserve assigned as instructor at the M.I.T. Radar School. After his discharge he became a part-time staff member at the Research Laboratory of Electronics, M.I.T., and since then he has been at M.I.T. in both a teaching and research capacity. His major interests have been in circuit theory, microwave field theory, and semiconductor devices. From 1951 to 1953 Dr. Adler was group leader of the M.I.T. Lincoln Laboratory Solid-State and Transistor Group. At present he is associate professor of electrical engineering at M.I.T.

Dr. Adler is a member of Sigma Xi and Eta Kappa Nu.

❖

S. V. Chandrashekhar Aiya, for a photograph and biography please see p. 619 of the March, 1958, issue of Proceedings.

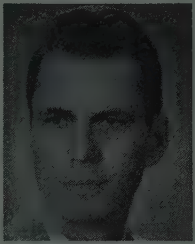
❖

H. Brueckmann

Dr. Helmut Brueckmann (SM'49–F'58) was born in Frankfort on Main, Germany, in 1906. He received the Dipl. Eng. degree in electrical engineering in 1930 from the Technical University of Berlin and the Doctor of Engineer degree in 1935 from the same university. From 1930 to 1937 he was a scientific consultant with the Central Technical Department of the German Reichspost. When the Research Institute of the German Reichspost was founded in 1937, he headed a section there until the end of the war.

After an interim period as Chief Transmitter Engineer of Radio Frankfort, he joined the newly organized technical institute of the broadcast stations in the western zones of Germany as head of the Broadcast Transmitter Branch.

Since 1948 Dr. Brueckmann has been a consultant with the U. S. Army Signal Research and Development Laboratories, Fort Monmouth, N. J.



E. A. Day

Edward A. Day was born in Saginaw, Mich., on March 4, 1919. He received the Bachelor of Science degree in mechanical engineering from the University of Michigan, Ann Arbor, Mich., in 1942.

From 1942 to 1946 Mr. Day served with the U. S. Navy. In 1946 he became associated with the Radiation Laboratory of the University of California, Berkeley, Calif. as a mechanical engineer.

From 1949 to 1956 Mr. Day was a research associate at the Department of Physics, University of Minnesota, Minneapolis, Minn.

Since 1956, he has been a mechanical engineer with the Midwestern Universities Research Association, Madison, Wis.

❖

R. Glicksman

Richard Glicksman was born on October 3, 1924, in New York, N. Y. He received the B.S., M.S., and Ph.D. degrees in chemistry in 1948, 1949, and 1953, respectively, from New York University. At N.Y.U., Dr. Glicksman studied the kinetics of diffusion controlled reactions for his thesis problem; he also investigated metal-metal ion exchange and adsorption with the use of radioactive silver, under an Atomic Energy Commission Contract (1951–1952).

He also held a graduate assistantship at N.Y.U. from 1950–1952.

Prior to his work at N.Y.U., Dr. Glicksman spent three and one-half years in the service, during which time he studied meteorology at the Massachusetts Institute of Technology, Cambridge, Mass.

He was a weather officer in the Army Air Force, and attained the rank of First Lieutenant.

Dr. Glicksman joined RCA Laboratories, Princeton, N. J., in January, 1953, and since that time he has been actively engaged in electrochemical research. His work has covered a wide range of topics, including corrosion, battery, and electrochemical polarization phenomena.

Dr. Glicksman is a member of the American Chemical Society, Electrochemical Society, Sigma Xi, and Phi Lambda Upsilon. He recently was recipient of a 1957 RCA Achievement Award for outstanding research.

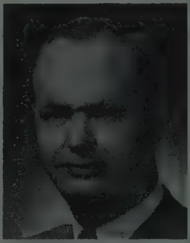
H. A. Haus

Hermann A. Haus was born in Ljubljana, Yugoslavia, in 1925. He attended the Technische Hochschule in Graz, Austria, from 1946 to 1948 and studied one term at the Technische Hochschule in Vienna. He attended Union College, Schenectady, N. Y., receiving the B.S. degree in 1949. He received the M.S. degree from the Rensselaer Polytechnic Institute, Troy, N. Y., in 1951 and the Sc.D. degree from the Massachusetts Institute of Technology Cambridge, in 1954.

He is now engaged in microwave tube research at the Research Laboratory of Electronics, M.I.T., and is also associate professor of electrical engineering.

Dr. Haus is a member of Sigma Xi.

❖



E. E. Lampi

Eugene E. Lampi was born on April 19, 1917 in Chisholm, Minn. He attended the Hibbing Junior College, majoring in electrical engineering. He received the B.E.E. degree in 1940, and the M.S. degree in physics in 1941, both from the University of Minnesota.

He was associated with the Naval Ordnance Laboratory, White Oak, Md., from 1941 to 1946, working on magnetic and acoustic instrumentation problems. He joined the Physics Department, University of Minnesota, as a research fellow in 1946. He received the Ph.D. degree in physics from that university in 1949.

From 1950 to 1957, he was a member of the Proton Linear Accelerator Group as a research associate. In 1957, Dr. Lampi joined the Bell Telephone Laboratories at the Allentown Laboratory as a member of the technical staff working on semiconductor diode development.

Dr. Lampi is a member of Eta Kappa Nu and Sigma Xi, and is a fellow of the American Physical Society.

❖

Gerald S. Lozier was born on October 3, 1930, in Londonville, Ohio. He received the B.S. and M.S. degrees in chemistry in 1952 and 1953, respectively, and the Ph.D. degree in 1956, all from Western Reserve University, Cleveland, Ohio.

Dr. Lozier held a teaching fellowship

from September, 1950 to September, 1953, and received the Electrochemistry Society, Cleveland Section, Award for the most outstanding student in Electrochemistry in the Cleveland Section area. From September, 1952 to December, 1954 he participated in ONR research at the Ultrasonic and Electrochemistry Research Laboratory of Western Reserve University on the investigation of ultrasonic effects on electrode processes. He joined RCA Laboratories in January, 1955, and has been doing battery research for the past two years.

G. S. LOZIER

Dr. Lozier is a member of the American Chemical Society and Electrochemical Society. He recently was recipient of a 1957 RCA Achievement Award for outstanding research.

◆

G. H. MILLMAN

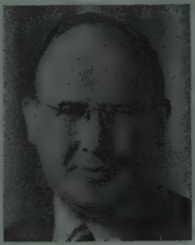
George H. Millman (SM'53) was born in Boston, Mass., on June 2, 1919. He received the B.S. degree in physics from the University of Massachusetts in 1947, and the M.S. and Ph.D. degrees in physics, from Pennsylvania State University in 1949 and 1952, respectively.

From 1942 to 1946, he was an electronics-radar officer in the United States Army Air Force, serving as officer-in-charge of an experimental radar project for the Far East Air Force. Military education consisted of communication training at Yale University and radar training at the Harvard-M.I.T. radar schools.

While at Pennsylvania State University, he was employed as a teaching and research assistant by the Department of Physics from 1947 to 1950, and as an instructor of engineering research by the Ionosphere Research Laboratory from 1950 to 1952 where he was engaged in the investigation of turbulence and wind movements in the ionosphere. In 1952, Dr. Millman became associated with the General Electric Company, working on problems related to airborne and ground radar systems analysis and radar antijamming research. Since 1955, he has been involved in experimental and theoretical studies in the field of electromagnetic-atmospheric propagation.

Dr. Millman is a member of the American Physical Society, American Association of Physics Teachers, Phi Kappa Phi, Sigma Pi Sigma, Pi Mu Epsilon, and Sigma Xi.

◆


C. K. MOREHOUSE

C. K. Morehouse was born in Boston, Mass., on April 8, 1917. He received the B.S. degree in chemistry in 1939 from Tufts College and the M.S. degree in chemistry from McGill University in 1940. He was a teaching fellow in chemistry at Tufts College from 1938–1939 and at Massachusetts Institute of Technology from 1946–1947. He was employed at the National Bureau of Standards as a research chemist in the field of electrochemistry. He received the Ph.D. degree from M.I.T. in February, 1947.

From 1947 to 1949, he was a supervisor in charge of battery research at the Western Cartridge Plant of Olin Industries. From 1949 to 1951, he was assistant director of research of the Electrical Division, Olin Industries, and from 1951 to 1953, he was research and development manager of that division. Dr. Morehouse joined the technical staff of RCA Laboratories, Princeton, N. J. in January, 1953 and since then has been in charge of battery research in the Physical and Chemical Research Laboratory. He has been issued seven patents.

Dr. Morehouse is a member of the American Chemical Society, Sigma Xi, Electrochemical Society, and Alpha Chi Sigma. He was recipient of a 1957 RCA Laboratories Achievement Award for outstanding research and was elected to the Executive Committee of the Battery Division of the Electrochemical Society for 1956–1958.

H. J. SCHULTE

Harry J. Schulte was born in Newark, N. J. in 1925. He received the B.S. degree in physics from Rensselaer Polytechnic Institute in 1948. During the period of his graduate work at the University of Rochester he worked on and with the 130-inch cyclotron, and participated in the early work on X rays from mesonic atoms. He received the Ph.D. degree in physics from that institution in 1953.

He was a research associate in physics at the University of Minnesota for the ensuing two years, participating in the construction of the 68-MEV Linear Accelerator.

Since July, 1955, Dr. Schulte has been a member of the technical staff at Bell Telephone Laboratories, Murray Hill, N. J., working on switching devices and digital computer systems.

Dr. Schulte is a member of the American Physical Society, Tau Beta Pi, and Sigma Xi.

◆

E. B. TUCKER

Edmund B. Tucker was born in Wolfville, Nova Scotia, on May 6, 1922. His undergraduate work was completed in 1943 at Mount Allison University, Sackville, New Brunswick. After spending two years in the Royal Canadian Navy Volunteer Reserve as a radar officer he attended Oxford University, Oxford, England, and received the Ph.D. degree from Yale University in 1951.

For five years Dr. Tucker was a member of the Linear Accelerator group at the University of Minnesota. In mid-1955 he joined the staff of the General Electric Research Laboratory, Schenectady, N. Y., where he is presently employed.

Dr. Tucker is a member of the American Physical Society and Sigma Xi.

Scanning the Transactions

Push-button electronic classrooms are being proposed in which automatic teaching devices would perform many of the more routine teaching activities, thus freeing the teacher for matters requiring greater skill. In this hypothetical classroom of the future the student would sit at a chair equipped with a special set of push buttons. A teaching machine would present the lesson by means of motion pictures or tape recordings, asking questions of the student at each stage of the lesson. The student would answer by pushing one of several buttons. Based on the student's response the machine would repeat or enlarge on the material just covered, or go on to the next part of the lesson. A master control unit would adjust the speed with which the machine took the student through the lesson to the ability of the individual student to comprehend, at the same time recording his progress for later study by the teacher, who could then bring his full skills to bear on the particular need of each student during supplemental sessions.

Are proposals such as this pipe dreams? The answer is not too important. What is important is that we live in an age of technological revolution, and in applying our newly found skills we should not overlook the important field of teaching aids. Electronics is supposed to be the branch of technology that specializes in the transmission and processing of information. Surely somewhere in its vast storehouse of new techniques and devices there must be some that, if properly applied, would greatly increase the efficiency and effectiveness of the educational process. (S. Ramo, "A new technique of education," IRE TRANS. ON EDUCATION, June, 1958; P. K. Weiner, "A proposed 'automatic' teaching device," *ibid.*)

The Medical Electronics Center of the Rockefeller Institute, under the direction of Dr. V. K. Zworykin, has just completed preparation of a document which must be regarded as a major publication milestone in the young and sprawling field of medical electronics. We have reference to an extensive bibliography covering 2200 articles dealing with the application of the various branches of electronics, such as acoustics, communications, television techniques, spectrophotometry and dielectric heating, to the many problems of biological and medical research, therapy, public health and related fields. With the increasing pace of scientific investigation, the localization of information pertinent to any specialized branch of investigation becomes increasingly difficult. In a poorly defined interdisciplinary field such as medical electronics, this problem is all the more difficult. The bibliography, which includes both a subject and author index, for the first time makes readily accessible a major fraction of the work that has been done to date in this vitally important field. It has just been published by the IRE Professional Group on Medical Electronics, and is now available from IRE headquarters at $2.50 per copy. ("Bibliography on Medical Electronics," published by PGME, June, 1958.)

Ceramics are usually thought of as insulators or dielectric materials. It may, therefore, surprise some to know there is one group of ceramics which may be classed as semiconductors or even conductors at room temperature. It is characteristic of these materials that as temperature increases their conductivity also increases, which is opposite to the effect found in metallic materials. The application of conductive ceramics to electronics is a wide-open field. These materials are only now in the embryo stage of development, research is moving very slowly, and the literature is practically void of any information on electronic applications. Among the most common ceramics in this class are the zinc, zirconium and tin oxides. Others in the group include various borides, carbides, nitrides and silicides. To date these materials have been used chiefly, as far as their electrical properties are concerned, as high-temperature resistance heating elements. However, they offer many interesting possibilities in the realm of temperature compensating devices, the fabrication of high-temperature waveguides, and indeed in a wide variety of applications involving high temperature conditions. The electronics industry stands much to gain by investigating these unexploited new materials. (Z. A. Post and P. E. Ritt, "Conductive ceramics," IRE TRANS. ON COMPONENT PARTS, June, 1958.)

Unmanned space ships capable of orbiting about the moon have passed from the realm of science fiction and are now an acknowledged goal of the near future. If we wish to place instruments on board and telemeter information back to earth, what will be the requirements for the radio system? If we figure on a 10 watt transmitter aboard the vehicle operating at 2250 mc, a 500 kc bandwidth receiver, and make certain reasonable assumptions concerning the characteristics of other parts of the system, it turns out we can readily span the 260,000 miles with a 4.8 foot antenna on the vehicle and a 60 foot receiving antenna on earth. However, if the same ship is to orbit about a nearby planet some 100 million miles away, the problem becomes more formidable. The transmitting antenna will have to be increased to 60 feet in diameter, the receiving antenna to 84 feet, and the receiver bandwidth reduced to one kilocycle. These and other requirements imposed on the system probably could not be met by presently realizable techniques. However, there seems little doubt that the kinds of improvements that are needed to make a planetary telemetry system feasible will be well within our capabilities in the near future. (H. Scharla-Nielsen, "Space ship telemetry," IRE TRANS. ON TELEMETRY AND REMOTE CONTROL, June, 1958.)

Photomultiplier tubes have become an important tool for measuring extremely short time intervals. The accuracy of such measurements, however, is limited by small differences in the transit times of electrons in the tube caused by variations in their initial velocities and path lengths. An ingenious scheme for determining the extent of these differences has been developed by making the tube take a picture of its own performance. By presenting the output pulse on an oscilloscope and comparing its length with the known length of the test input pulse, it has been determined that the transit time deviations of commercial photomultipliers is on the order of one millimicrosecond. While this may seem trivial, it is a significant time interval to such people as nuclear physicists who wish to measure radioactive phenomena in the millimicrosecond range. (M. H. Greenblatt, "On the measurement of transit time dispersion in multiplier phototubes," IRE TRANS. ON NUCLEAR SCIENCE, June, 1958.)

The future of electronics lies to a great degree in its many applications to industrial processes. A brief glimpse of the diversity, as well as the growing importance, of this still-young branch of electronics is afforded by the program of last fall's annual Industrial Electronics Symposium. A glance at the menu of 16 papers reveals a veritable technical smorgasbord, from which we have culled the following sample tidbits: (1) a transistorized telemetering device for transmitting torque data from the rotors of high-speed machinery, (2) automatic machine tool control, (3) magnetic pickups for counting metal parts, (4) electrolytic method of counting and analyzing the size of minute particles, (5) gas analyzer based on speed of sound measurements, (6) electronic sorting of mail, (7) photoelectric control for automatic registration in multicolor printing, and (8) industrial measurements with X rays. (IRE TRANS. ON INDUSTRIAL ELECTRONICS, May, 1958.)

The semiconductor is making steady inroads into TV receiver circuits, judging from the latest issue of Broadcast and Television Receivers TRANSACTIONS. All three papers in the issue were devoted to one aspect or another of the subject.

Reverse biased junction diodes, which act as voltage variable capacitors, are proving to be practical for fine tuning and FM automatic frequency control circuits. Meanwhile, investigations into transistorized horizontal deflection, high voltage, and sound sections show a number of important advantages over the corresponding tube circuits, while the few remaining disadvantages are awaiting only the arrival of improved transistors before they, too, are overcome. (IRE Trans. on Broadcast and Television Receivers, June, 1958.)

Electronic simulators, which have been used for a number of years to solve complex problems in the design and operation of various systems, are now finding important use in the study of heat transfer systems in nuclear power plants. Thus, electronics is placing still another important instrument at the disposal of the nuclear engineer, the analog computer. (S. O. Johnson, *et al.*, "Simulation of hot channel boiling in water-cooled reactors," IRE Trans. on Nuclear Science, June, 1958.)

Books

Physique Electronique des Gaz et des Solides by Michel Bayet

Published (1958) by Masson et Cie, Editeurs, 120 Boulevard Saint-Germain, Paris 6, France. 220 pages +21 appendix pages+2 index pages+1 bibliography page. 81 figures. 9½×6½. 4.900 fr.

This book by Professor Bayet is intended for the graduate student and the specialist interested in the kinetics of electrons in the presence of other bodies. It is a text book for an advanced course in electronics.

The book starts with a review of fundamental concepts of statistical mechanics and of the two-body problem in classical mechanics. Then the author deals with the kinetic theory of gases involving up to three different types of particles. In Chapters III and IV Professor Bayet develops in detail the more sophisticated theories pertaining to a Lorentz gas and to the electromagnetic properties of plasmas. Then, for the sake of completeness, the multitudinous phenomena which can occur in ionized gases are covered in a brief description. The last two chapters are devoted to free electrons in metals and semiconductors. The book concludes with a set of appendices giving valuable relations for frequently used mathematical operations.

Those who only wish to get acquainted with the physical principles of gaseous electronics will appreciate the brevity of the book and regret that it is not available in English. About one hundred fifty pages are devoted to the explanation of various phenomena. Nowhere does the author dwell on experimental or technological detail. For experimental data (and for an extensive bibliography) the reader is referred to pertinent selections of the vast literature in this field.

The introductory chapter is somewhat sketchy because fundamental relations are introduced without derivation—more elementary texts are available for this. On the other hand, the advanced reader unfamiliar with the symbolism may not be able to start with the more advanced chapters without first browsing through the beginning of the book in search of definitions.

The distinguishing feature of this book is its exclusive concern with the kinetics of the electron gas with or without the interaction of other particles (ions, molecules, holes or periodic structures).

M. Bayet is the product of France's outstanding school for physicists, the Physics Laboratories of the Ecole Normale Superieure of Paris whose director, Professor Y. Rocard, has written the preface.

J. I. Pankove
RCA Labs.
Princeton, N. J.

The Exploration of Space by Radio by R. H. Brown and A. C. B. Lovell

Published (1958) by John Wiley & Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. 201 pages+5 index pages +xii pages. 132 figures. 9¼×6. $6.50.

Considering the temper of the times it is not surprising that a book which is essentially a revision of *Radio Astronomy* by A. C. B. Lovell and J. A. Clegg, published in 1952, should now appear with the above title. Its appearance is timely not only for the great surge of interest in space research, as astronomy is now called, but because it has been three years now since the last book was published in English on the same general subject: *Radio Astronomy* by J. L. Pawsey and R. N. Bracewell. During these years several important advances and discoveries have been made.

The authors of *The Exploration of Space by Radio* are both eminent radio astronomers. Dr. Lovell is the Director of the Jodrell Bank Experimental Station of the University of Manchester, England. His foresight and courage are largely responsible for the erection of the world's largest steerable radio telescope, a 250-foot diameter reflector which has been nearly a decade in the making. His specialty is radio meteor astronomy; he is the author of the comprehensive treatise, *Meteor Astronomy* (Oxford, 1954). R. Hanbury Brown is noted for his outstanding ability in both electronics and astronomical research. His principle field of investigation has been the mapping of galactic radio emissions using the 218-foot fixed parabolic reflector at Manchester. In recent years he has collaborated with R. Q. Twiss in developing and exploiting a radically new method of measuring the size of both radio "stars" and optical stars using their principle of a correlation interferometer.

Their book is to be compared with *Radio Astronomy* by Lovell and Clegg which appeared six years ago. An appreciable fraction of the figures and many pages of text in the book under review are taken directly from the book by Lovell and Clegg. Both books were written for the layman interested in radio or astronomy. The treatment is non-mathematical and clearly descriptive but is less adaptable for classroom use than is the text by Pawsey and Bracewell.

An outstanding feature of the book under review is the excellent reproduction of 27 photographs; ten are related to the 250-foot radio telescope. The last nine pages of the book are devoted to a description of this impressive instrument, to its general design and construction, to its observational program and its use as a radar antenna. The longest section covered is on radar studies of meteors. The second longest chapter is on techniques of radio astronomy. The radio engineer should be cautioned that he will find only block diagrams of the various arrangements of simple radio telescopes, interferometers, multi-antenna systems, radio spectrographs and polarameters. This chapter is clearly written and is a pleasure to read. However, may I point out that in Figure 33, on page 48, the interference fringes should be drawn up and down, not slanted. The next topics covered, in the order of space allocated to them, are: continum radio emission from the galaxy, solar radio emission, some properties of radio waves, the moon, the earth satellite and planets, a review of astronomy, hydrogen line radiation, scintillation of radio stars, and radio emission and reflection from aurora.

To the reviewer it was disappointing to find that the treatment of solar radio emission was not up to the high standard of the chapters on meteors and radio techniques. The over-all treatment of solar radio emission is a revised version of that given in the book by Lovell and Clegg, but was not brought up to date. The only new feature is the inclusion of a two-page discussion of cosmic radio wave emission from the sun during the great February 23, 1956 solar flare event. There is a one-sentence mention of dynamic spectra of solar bursts; a development in the early 1950's by Paul Wild which has made possible a major advance in the nderstanding of radio emission from the un. There is no mention of polarization of olar bursts, of the size of bursts, their spec- rum or any recent work on the generation f radio waves from the sun. The occultation f the crab nebula by the solar corona is riefly mentioned.

A book of this nature is usually balanced favor of the interests of the authors but is regrettable that no mention is made of nvestigations in France, Japan, Germany, he Scandinavian countries and, with the xception of the theoretical work by Shklovky and Ginzburg, Russia. The coverage of adio astronomy in England, Canada, nited States and Australia is more com- lete than in the earlier book by Lovell and legg.

The book is very attractively arranged nd put together. Although it is not entirely p to date in several areas, it is easy to read nd is a good summary of much of the ma- erial treated.

The authors are to be congratulated in riting this popular book on radio astron- my. It is widely hoped that they will follow his up with a treatise on radio astronomy chniques.

F. T. HADDOCK
Univ. of Michigan
Ann Arbor, Mich.

rinciples of Electrical Measurements by . Buckingham and E. M. Price

Published (1957) by Philosophical Library, Inc., E. 40 St., N. Y. 16, N. Y. 592 pages+8 index pages xxiii pages. 418 figures. 8¼×6. $15.00.

This book covers the field of electrical easurements by breaking the various ethods and instruments down into specific ethods such as deflection instruments, de- ection methods, potentiometer measure- ents, bridge methods, methods using ermionic valves, resonance and hetero- yne methods, and so on. At places this vision breaks down in favor of a division usage, chapters such as the one on power stem measurements or the one on the easurement of some non-electrical quanti- es cut across a variety of measuring sys- ms and methods.

The book is not designed specifically as a xt, although, it could be used by students the advanced phases of electrical en- neering as a text. By and large the flavor the book is that of the standard type of easurements book giving the greatest em- hasis to d-c and low frequency a-c measure- ents with only relative small part of the ook on the high frequency measurements. othing at all is included on measurements traveling wave systems such as wave uides or coaxial lines. The book covers 592 ages with 13 chapters of which a little over vo chapters are devoted to radio frequency ork. These chapters comprise approxi- ately 130 pages.

The work on radio frequency measure- ents is really very well done, even though is sketchy at times. For example elec- onic accounting, including scalers, gets a eatment two pages long. The development f the electron tube voltmeter is done very ell and throughout this section of the book here are small examples of the importance f the magnitudes of the quantities involved one in small type. A person studying these really should get a very good background in the principles described. The reviewer differs with the authors in regard to their discussion of input resistance of thermionic voltmeters since the authors do this in terms of the amount of power absorbed by the voltmeter whereas the reviewer prefers to think of the resistance as something which because of the input impedance of the source being measured will cause the voltmeter reading to be less than it should be. These two concepts are not always the same.

The introduction to the resonance circuit theory is exceedingly well done. In this chapter quartz crystals are discussed and in a few pages the authors cover the fundamental and basic characteristics of the crystal in a very excellent manner.

The rest of the book devoted primarily to dc and low frequency measurements is quite thorough and quite well written. In the section on deflection instruments the discussion of torque equations and scale shapes is most excellent and a student can learn well the theory of operation of these instruments from this book.

There are practically no references in this book to original work or to other books. This might be viewed as a defect inasmuch as a reader wishing to pursue a particular point might like to go beyond the boundaries of the book and explore the situation in greater detail.

If a reader does not already have in his library a basic book on electrical mesaurements, this would be an excellent book for that spot on the bookshelf.

G. B. HOADLEY
North Carolina State College
Raleigh, N. C.

An Introduction to the Theory of Random Signals and Noise by W. B. Davenport, Jr. and W. L. Root

Published (1958) by McGraw-Hill Book Co., Inc.' 330 W. 42 St., N. Y. 36, N. Y. 382 pages+17 appendix pages+6 bibliography pages+3 index pages+ix pages. Illus. 9¼×6¼. $10.00.

This well-planned and carefully-executed book is an expansion of notes prepared some years ago by Dr. Davenport for a one-semester graduate electrical engineering course at M.I.T. The book is divided roughly into two parts. The first half deals with the "development of those elements of probability theory and statistics which are particularly pertinent to a study of random signals and noises in communications systems." The second half is devoted to applications.

Specifically, the first half begins with a discussion of probability functions and random variables, and continues with averages, correlation, laws of large numbers, and spectral analysis. The first half concludes with careful treatments of two random processes—shot noise in vacuum tubes and the Gaussian process. The applications section starts with the analysis of the performance of linear systems with random inputs, including the derivation of some optimum linear systems for smoothing, prediction, etc. The following chapters discuss the performance of certain nonlinear systems, specifically square-law detectors or vth-law devices (including ideal limiters). The book concludes with an excellent short introduction to the statistical detection of signals, with examples from radar and communications applications.

The book is clearly intended for the theoretically-inclined engineer and not for the mathematical specialist. The specific prerequisites assumed are "some electrical network theory and an advanced engineering calculus course containing Fourier series and integrals," but what would really seem necessary is not so much a knowledge of particular topics as a degree of mathematical sophistication. The authors disavow any attempt at rigor, but they have not allowed their concern for lucidity to tempt them into easy rationalizations, careless arguments, or false generalizations. For example, consistent use is made of the Karhunen-Loéve expansion of a random function over a finite interval, rather than the more familiar but less satisfactory trigonometric expansion. As a result the average engineering graduate student will likely find parts of the book rather difficult, but for the most part these sections can be skipped in a first course without serious loss in continuity. On the other hand, the more advanced reader will appreciate the numerous specific references to the literature and the excellent bibliography and index. A number of problems, both illustrating and extending the text, are provided for each chapter.

This book is certain to receive an enthusiastic welcome from both students and teachers seeking a readable yet careful introduction to what often appears to be a confusing and esoteric subject. But it should prove equally useful to the industrial research engineer who is dissatisfied with *ad hoc* methods of handling random signals and who desires a more orderly treatment.

W. M. SIEBERT
M.I.T.
Cambridge 39, Mass.

Atmospheric Explorations, ed. by H. G. Houghton

Published (1958) by The Technology Press of M. I. T. and John Wiley & Sons, Inc., 440 Fourth Ave., N. Y., 16, N. Y. 125 pages +x pages. Illus. 9¼×6. $6.50.

This book is a collection of five papers on subjects relating to the atmosphere which were presented at the Benjamin Franklin Memorial Symposium of the American Academy of Arts and Sciences in 1956. The choice and treatment of the subjects in the papers are selective rather than comprehensive. This approach was chosen in keeping with the spirit of the celebration of Franklin's two hundred and fiftieth birthdate as illustrative of the keen analytical approach which would be expected of him if he were living.

The authors are eminently qualified to present the interpretation of their own work and the work of others in their particular fields. The belated publication of the papers in book form has reduced the significance of the articles as original contributions, but these distinctive papers are a fitting tribute to one of America's greatest scientists.

The first three papers discussing various phases of atmospheric electricity are as follows: *The Electrification of Clouds and Raindrops* by Ross Gunn, Director, Office of Physical Research, U. S. Weather Bureau; *The Formation of Electrical Charges* *in Thunderstorms* by J. P. Kuettner, Geophysical Research Directorate, Air Force Cambridge Research Center; and *Positive Streamer Spark in Air in Relation to the Lightning Stroke* by L. B. Loeb, Professor of Physics, the University of California, Berkeley.

Dr. Gunn discusses ionization in the clear atmosphere and in water droplet clouds, and presents experimental results of charge distribution measurements by the Weather Bureau in a cloud chamber. He compares these results with his theory of the ionization of water drops.

Dr. Kuettner, starting from the original observation of Franklin and the English physicist Wilson concerning the polarity of clouds, discusses the processes for segregation of charges in thunderstorms.

As a logical extension of the first two papers, Dr. Loeb describes work relating to the discharge of clouds through lightning strokes with emphasis on the positive streamer spark.

The last two papers deal with two views of the upper atmosphere and are as follows: *A Meteorologist Looks at the Upper Atmosphere*, by Harry Wexler, Director of Meteorological Research, U. S. Weather Bureau; and *Phenomena of Radio Scattering in the Ionosphere* by H. G. Booker, Professor of Electrical Engineering, Cornell University.

Dr. Wexler discusses meteorological processes in the upper atmosphere with emphasis on the upward and downward propagation of storms as extensions of the more routinely used low level development and horizontal movements of storms. Some efforts are made to discuss possible direct linkages between solar and atmospheric phenomena.

Dr. Booker's approach to the upper atmosphere is through the use of vertical soundings with radar and long range radio communications. Improved measurement techniques and extension of frequency ranges have made possible a more complete understanding of the ionosphere.

Although this book is recommended neither as a text nor as a reference, it serves admirably to chronicle the spirit of scientific history in the making.

A. W. STRAITON
Univ. of Texas
Austin, Tex.

Soviet Education for Science and Technology by A. G. Korol

Published (1957) by The Technology Press of M.I.T. and John Wiley & Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. 417 pages+47 appendix pages+16 bibliography pages+26 index pages+xxv pages. 9¼×6¼. $8.50.

This very competent and cautious book on the Soviet educational system derives from a project which was begun by the Center for International Studies of the Massachusetts Institute of Technology in 1953 and was continued after 1955 under a grant from the Carnegie Corporation of New York. In addition to the staff of the Center, many faculty members of M.I.T. assisted in the evaluation of the documentary material, such as Soviet textbooks, examination questions, and specific curricula details. Much of the quantitative information could appear as astounding progress in broad general education; but fortunately, Mr. Korol in many places points out significant qualitative factors to set the total program into the proper perspective. Though the over 400 pages of text, supported by 3 charts and 56 tables and many appendices might give the impression of elaborate presentation of facts that in many other places have been so simply summarized, it should be emphasized that the simpler presentations have often given completely wrong impressions and have led to alarming conclusions. Anyone interested in Soviet education in the fields of science and technology will be well rewarded in reading this rather comprehensive treatise. In particular, attention should be directed to the author's comments and reflections which represent his own evaluation of the comparative advantages and disadvantages of the Soviet educational system. And system, indeed, it is, centrally directed and supervised with the objective of careful and forceful indoctrination in the Communist doctrines, giving education not as we understand it in the Western World, but as a planned activity fitting into the over-all pattern of a planned economy.

The major part of the book, Chapters 5 to 10 inclusive, is devoted to the Soviet counterpart of undergraduate college education in science and technology. In particular, historical data are given concerning growth of the university and institute patterns and the successive changes in emphasis. In 1955, the last year of complete data available for inclusion into this book, the enrollment in all technical professional schools was 450,000 full-time students, 100,000 evening students, and 100,000 correspondence course students, representing a total of 35 per cent of the entire registration in higher education. It is this great emphasis upon one phase of higher education which has given rise to the warnings. Yet, if we follow the author's qualitative comments and realize the rigidity of curricula and the extreme specialization, we learn to attach different significance to these numbers. Individually, the chapters carry the self-explanatory titles: the institutional system; selection, enrollment, and graduation; the academic plan; sample curricula in mechanical engineering, in physics, and in mathematics (at a teacher's college); teachers, textbooks, and facilities; the teaching process.

To illustrate the preparation for college, Chapters 2 and 3 deal with the ten-year school roughly equivalent to our elementary and high school periods, though more strenuous and with much emphasis on mathematics and the sciences. Again, the author examines in detail organization and curriculum, instruction, textbooks, and examinations. There appears little doubt that the rigorous schedule and program of this 10-year school is a very direct and effective preparation for college.

Chapter 4 is devoted to the secondary engineering (industrial) technical schools, so-called technikums, which furnish well-trained technicians in much larger numbers than available in this country. The course runs for 2½ years and the enrollment has increased from 187,000 in 1940–1941 to 843,000 in 1955–1956, a trend that is prob-
ably most significant in any comparison o
relative technical training in this countr
and in Soviet Russia.

The first chapter gives a general in
troduction to the Soviet system of mass edu
cation, and outlines all phases of general an
secondary education together with the "Stat
Labor Reserve" and its training programs.

For anyone really interested in th
serious comparison of Soviet vs U.S.A. edu
cation, this book is practically imperativ
reading since it points out so ably the differ
ent atmospheres out of which objectives o
education have been formulated.

ERNST WEBE
Polytechnic Inst. of Brookly
Brooklyn, N.

An Introduction to Digital Computers b R. K. Livesley

Published (1957) by Cambridge University Pres
32 E. 57 St., N. Y. 22, N. Y. 52 pages+1 bibliograph
page+viii pages. Illus. 8¾×5¾. $1.75.

This is a brief introduction to the bas
principles of operation of digital compute
and to the types of routine problems whic
can be solved with such machines. The boo
is intended primarily for the engineer
other person who is more interested in th
possible applications of digital compute
than in the detailed design of computin
circuits. For this reason, emphasis is place
on programming and on over-all syste
operation. The equipment, devices, an
circuitry which can be used to constru
digital computers are discussed only whe
necessary to help explain the general oper
tion. The author has avoided detailed di
cussions of mathematical techniques an
comprehensive descriptions of the idiosy
crasies of particular machines.

The book contains four chapters. In th
first chapter, The Elements of Programmin
the author explains the fundamentals
digital computer operation and the use of
program of machine instructions by illu
trating how a simple mathematical proble
can be mechanized and solved. The discu
sion of elementary programming is co
tinued to include jump instructions, addre
modification, and some information abo
the instruction codes used in real machine

Some of the "hardware" used in the co
struction of actual machines is described
Chapter 2, titled Input, Storage and Outp
of Numbers. This chapter contains bri
descriptions of the most widely used bina
storage systems and types of input-outp
equipment. A short discussion of decim
and binary systems of numbers is also i
cluded. The reviewer feels that some di
cussion of the devices and techniques us
in the computing circuits should have bee
included in this chapter. For instance, t
use of semiconductors and vacuum tubes
barely mentioned. Also, the author makes
statement in the second paragraph on pa
19 which gives an erroneous impression
the speeds obtainable with modern digit
computers. He states that the access ti
of the high speed stores of most mode
computers is of the order of a millisecon
whereas a more correct figure would be te
of microseconds.

The third chapter, The Organization of rogrammes, describes the way in which arge programs are usually constructed, and onsiders some of the techniques which ake programming easier.

In the final chapter, The Solution of Enineering Problems, the author discusses n very general terms some of the problems hich can be solved with digital computers. hese include problems in linear and nonnear algebra, ordinary and partial differntial equations, and function tabulation.

Although this book is very short, the uthor has managed to present a broad picure of the outstanding features of digital omputers in such simple language that the onspecialist should find it easy to read and nderstand. Coverage on programming and eneral system operation is especially good.

W. B. Cagle
Bell Telephone Labs.
Whippany, N. J.

rinciples of Electronic Instruments by . R. Partridge

Published (1958) by Prentice-Hall, Inc., 70 Fifth ve., N. Y. 11, N. Y. 383 pages+9 index pages+xiv ages. Illus. 9¼×6¼. $11.00.

As stated by the author in the preface, e book is essentially the result of teaching course in electronic instrumentation and easurements. This field has become so exensive that it would of course be well nigh npossible to cover it in even reasonable deil in one lecture course, or one book of ome 380 pages, as the present one. In such ondensed presentations the subjects covred will not all receive the same degree of ondensation, since any teacher or writer ill have a special interest in certain areas, hich will then necessarily receive a more etailed treatment than others. When such book is used as a text in a lecture course, is is not a serious handicap, since the priary purpose of education should not, and annot be to cover every detail and applicaon, but rather to show the student the rinciples involved and let him then apply is knowledge to other problems of a simir nature. A practicing engineer, on the ther hand, who hopes to find a reference ook on electronic instrumentation and ethods, might be disappointed; his chances f finding a description of just the instruent or method he may be interested in at e moment, are naturally rather slim. Hower, it should be stated that the literature eferences at the end of each chapter are of ecided help in this respect.

The book can be divided into roughly wo parts. The first 12 chapters, representing bout 60% of the text, deal with electronic struments. There are three chapters on dc nd ac vacuum tube voltmeters, in the ourse of which such well known instruents as the Ballantine and Hewlett-Packrd meters are described in detail. One hapter—good reading for any electrical ngineer—deals with that perennial favorite ubject of confusion: rms responsive, averge value responsive and peak responsive intruments. Other chapters deal with electroeter tubes, electronic wattmeters, frequeny measurements, phase meters, Q-meters, -angle meters and digital displays.

The second part of the book deals with e application of electronic measurement techniques in the field of non-electrical quantities. A number of the better known transducers, such as SR-4 strain gages, linear variable differential transformers and accelerometers are discussed briefly. Other chapters deal with the measurement of velocity of gases or liquids, of time, measurements in the field of sound, light, pressure, temperature and radio activity. While these chapters are also far from complete, they give a valuable birds-eye view of what electronic instrumentation can accomplish. The reader desiring more detailed information will again find the references at the end of each chapter of help. Incidentally, in the lists of references on pages 191, 210 and 255, the designation "Communications and Electronics" should read: "Transactions of the AIEE, Part I, Communications and Electronics."

The book can be recommended to the teacher planning a course in the field of electronic instrumentation. It will also be of value to a person who wishes to obtain a general picture of this field.

Walther Richter
Consulting Electrical Engineer
Milwaukee 17, Wis.

Zone Melting by W. G. Pfann

Published (1958) by John Wiley & Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. 208 pages+21 appendix pages+6 index pages+xvi pages. Illus. 9¼×6. $7.50.

It is fortunate that the world-authority on zone-melting, W. G. Pfann, was able to publish this important book, before less qualified authors "made hay" of the urgent need for such a volume, as has often happened in other fields. Although Kapitza, as well as Andrade and Roscoe, had made use of the zone-melting process years before World War II, it was not until Pfann pioneered in the many varied applications of this technique, particularly in semiconductor purification, that its potentialities were realized.

The book is singularly comprehensive covering every aspect of zone-melting from the fundamental principles to the many ingenious applications. Most of the new ideas in this volume were originally conceived and tested by the author and his co-workers, which gives him an intimate familiarity with the subject.

The introduction (first chapter) outlines the principle of zone-melting and scans the contents of each chapter in a few sentences; a most effective way of familiarizing the reader with the pertinent terminology. The second chapter treats the process of freezing and the associated segregation of solutes which leads to the definition of the "distribution coefficient" and methods of its determination. The "Theory of Zone Refining" is briefly and concisely presented in the third chapter; easy to understand without sacrificing details or accuracy.

The most outstanding chapter is the fourth on "Techniques of Zone Refining" where little is left to the imagination of the reader. Every conceivable modification of the zone refining principle seems to be described, so that it should prove most valuable to the reader interested in the practical application of this process. The fifth chapter on the "Application of Zone Refining" gives a few examples of materials which have been successfully purified by zone melting. Chapter Six on "Continuous Zone Refining" is of particular interest for the production-oriented reader. Many heretofore unpublished methods are described together with their theoretical foundation. "Zone Leveling and Single Crystal Growth" are dealt with in the seventh chapter with a section on "Dislocations and Crystalline Perfection."

The eighth chapter, "Methods of Perturbing the Concentration," goes into metallurgical and diffusion techniques for the control of the concentration distribution of the solute, such as impurities in semiconductors. The text deals primarily with semiconductor examples, among them Pfann's remelt method of producing *p-n* junctions and *p-n-p* transistor structures.

"Temperature Gradient Zone Melting," discussed in the last chapter, is probably the most intriguing extension of the zone melting principle. This technique produces motion of a finite molten volume within a solid body in the direction of a constant temperature gradient. It can be used for *p-n* junction fabrication, single crystal growth and even the determination of diffusivities in liquids.

An appendix with twenty generalized curves of solute concentration versus distance along a zone-refined ingot for different distribution coefficients will be invaluable for the reader interested in the quantitative appraisal of zone-melting for specific purposes.

The terminology seems somewhat arbitrary in spots and certain headings are not entirely clear, at least to the non-metallurgist. Although this does not impair the general usefulness of the book, it is a minor blemish in view of the expected broad readership from many different fields.

Zone Melting is an outstanding book for engineers, physicists, chemists and metallurgists generally interested or directly concerned with metallurgical methods. Emphasis on the application to semiconductor problems render it "a must" for anybody engaged in work on semiconductor materials and devices. This relatively small volume contains a surprising amount of new and practical information.

D. A. Jenny
RCA Labs.
Princeton, N. J.

Feedback Control Systems by O. J. M. Smith

Published (1958) by McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 643 pages+12 appendix pages+35 index pages+xviii pages. Illus. 9¼×6¼. $13.50.

This is an advanced book which will be most useful for these with some experience in the field of automatic control. The variety of material covered is impressive, the approach to various techniques of analysis and synthesis is unique, and the enthusiasm of the author in developing his ideas is clearly apparent.

The introductory chapter, though short, explains the general principles of feedback in terms of the author's philosophy, and varied examples of application such as those in production, inventory, transportation, economic, and society control are given. This is significant because reference to these various fields is made throughout the book to make the reader constantly aware of the versatility of automatic control.

A number of contributions to techniques of analysis and synthesis of control systems are presented for the first time in a textbook. One of the first that is introduced is the *L* plane which is essentially a log magnitude-phase angle diagram with the gain in nepers and the phase in radians. The important point is that the scales are arranged to have one neper equal to one radian. With this scale selection, vector lengths on the chart have meaning, and the relation between the frequency response plot and the locations of the critical closed loop poles in the *s* plane can be established from the corresponding complex vector margin and the vector attenuation rate on the *L* plane.

The author stresses his belief that the basis for understanding the operation and performance of a feedback control system must be obtained from a study of the relationships between the open and closed loop roots in the *s* plane. To illustrate this relationship, a number of elaborate open and closed-loop pole-zero plots with contours of constant phase and magnitude are shown. The importance of the *s*-plane saddle points in factoring polynomials in plotting root loci, and in the relation between open and closed loop roots is frequently discussed. This subject is further emphasized in Chapter 3, *S*-Plane Analogs, where the details of constructing, calibrating, and using potential analogs, conducting paper, and electrolytic tanks, as well as geometric analogs are discussed in unusual detail.

A large portion of the book is based on the use and manipulation of block diagrams, and this topic is introduced in a chapter on multiple loops. A complete discussion of unilateral, bilateral, reciprocal, and linear elements is given as a foundation for transforming circuits and equations into block diagrams and blocks into different types of systems.

Another chapter, Power Spectra, introduces the concept of random signals and this is explained in terms familiar to electrical engineers. This practical interpretation may be of particular interest to those who have only a mathematical acquaintance with random signals. A particularly noteworthy section explains how different random signals are combined and used when they are correlated. This is a subject which is usually omitted from most papers and texts.

This chapter, Power Spectra, concludes the first part of the book titled "Linear Analysis." There are three other parts: "Linear Synthesis," "Steady-State Nonlinear Analysis," and "Nonlinear Synthesis."

The last three parts of the book are as informative and thought provoking as the first. Optimum linear synthesis based on minimizing the mean square error is considered both from a rigorous and heuristic viewpoint. In fact, several different interpretations of the optimum filter philosophy are given in practical engineering terms. The theoretically optimum filter is converted into practical feedback system configurations which minimize nonlinear component effects by block diagram manipulations.

Practical considerations such as selecting components, networks, and tolerances, and distributing power and locating components in the loops are discussed.

Methods of analyzing and synthesizing systems with distributed parameters and transportation lags are treated throroughly in a separate chapter, but sampled data systems are not included.

The fundamental concepts of nonlinear control are introduced in a study of relay operation where the describing function is derived for triangular and gaussian inputs as well as for sinusoidal inputs. Subsequently, the nonlinear analysis is developed to include deadzone, different types of hysteresis, backlash, and coulomb friction. Actually, 150 pages are devoted to the subject of nonlinear analysis and another 100 are concerned with nonlinear synthesis.

Nonlinear synthesis with prediction control, or switching functions, is based on phase plane analyses and this is extended in concept to phase space. The nonlinear switching control is extended to systems with saturation, complex poles, dead time, and multiple saturations.

The last chapter in the book concerns the analysis, synthesis, and realization problems in the construction of carrier frequency systems. The analysis is based on pole zero locations, and there is considerable discussion on components, modulators, demodulators, and various types of linear and nonlinear compensating networks.

It should be mentioned that each of the 18 chapters has an excellent introduction and summary, and that each chapter ends with 20 to 50 problems and a bibliography concerning the subject of the chapter.

There are several minor deficiencies that should be mentioned. One is that standard symbols and terminology as proposed or approved by automatic control committees have not been used. However, it is in keeping with the theme and philosophy of the book because the general approach to all of the subject matter is somewhat different from the conventional. Although some readers may object to different treatments of some of the techniques that are well established in other textbooks, others will find this book capable of stimulating new ideas.

It does seem, however, that another minor deficiency may be found in the style of writing. In his enthusiasm, the author frequently dashes from one idea to another, and it is not always clear whether some of his conclusions and counsel are founded on a rigorous proof, experience, general philosophy, opinion, or imagination. In any case all of his viewpoints are interesting although it appears that a few of his original interpretations may be more complicated and inefficient than some which are more commonly known. However, whether or not the reader agrees with the author's philosophy, it is bound to be stimulating and challenging to graduate students and to experienced persons alike. Certainly, it is a book which will prove to be a valuable reference for all who are seriously interested in feedback control system analysis and design.

G. S. AXELBY
Westinghouse Elec. Corp.
Baltimore, Md.

Electronic Semiconductors by Eberhard Spenke, translated by D. Jenny, H. Kroemer, E. G. Ramberg, and A. H. Sommer

Published (1958) by McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 379 pages+14 appendix pages+7 index pages+xxvi pages. Illus. 9¼×6½. $11.00.

This book is a translation of the second German edition of Eberhard Spenke's book *Elektronische Halbleiter* which appeared in the German edition several years ago. The translators have been true to the original spirit of the book; however, they have followed American practice with respect to nomenclature and symbols and have added a series of problems at the end of each chapter. This reviewer feels that the additions made by the translators have increased the value of the book which, in its present form, should make an excellent textbook in an introductory course to the fundamentals of semiconductor physics.

The book is divided into two main sections. The first five chapters deal with the conduction mechanism of electronic semiconductors and the physics of rectifiers and transistors; while the last five chapters deal with the fundamentals of semiconductor physics. In the first part the subjects considered are:

I. The Conduction Mechanism in Electronic Semiconductors
II. The Nature, Models, and Reactions of Impurities and Imperfections
III. The Hole
IV. The Mechanism of Crystal Rectifiers
V. The Physical Mechanism of Crystal Amplifiers (Transistors).

In the second part chapters are devoted to:

VI. Approximation Methods in the Quantum Mechanics of the Hydrogen Molecule
VII. The Band Model
VIII. Fermi Statistics of the Electrons in a Crystal
IX. The Dynamic Approach to Impurity Equilibria and the Inertia of Impurity Reactions
X. Boundary Layers in Semiconductors and the Metal-Semiconductor Contact.

Dr. Spenke's treatment is for the most part clear and easy to follow. The bibliography, while not extensive, does nevertheless make adequate reference to the original literature for the purposes of a textbook.

In short, it seems to this reviewer that this book is an excellent introduction to the fundamentals of semiconductor physics. With regard to the treatment of semiconductor devices the book is not as complete as one might hope. This is largely due to the fact that the first German edition was written in 1952 and the revisions of the second edition of 1954 or thereabouts seemed principally in extending the references to the literature. Thus, since the field of semiconductor devices is a very rapidly moving one indeed, one regrets that some of the latest contributions could not have been included. Nevertheless, the book is recommended as an introductory text for those students who wish to learn something about semiconductor physics and particularly as applied to rectifier and transistor problems.

G. C. DACEY
Bell Tel. Labs.
Murray Hill, N. J.

Photosensitors by W. Summer

Published (1958) by The Macmillan Co., 60 Fifth Ave., N. Y. 11, N. Y. 592 pages+61 bibliography pages+2 appendix pages+18 index pages+xvi pages. Illus. 8¾×6. $21.00.

This book contains a comprehensive review of photoelectric devices and their uses in industry, including two thousand references plus a list of patents in this field. Part I is devoted to a description of these devices and their characteristics, while Part II describes their industrial applications and the uses of related equipment.

Part I contains nine sections as follows:

1. Historical background.
2. Applications:
    A comparison of visual against photoelectric reaction time; fatigue, etc.
3. Photosensitor and the human eye to photoelectric devices, covering color, depth perception and spectral response.
4. Photosensitors.
    A description of the general characteristics of photoelectric devices as well as outline of the various types including photovoltaic cells.
5. Basic Circuits.
    This covers amplifications, shielding, wheatstone bridges, etc.
6. Optical Equipment.
    A fairly complete compilation of the physics of optics and light and its correlation to photosensitors.
7. Sources of Radiant Energy.
    A definition and description of various radiant energy sources such as light sources, monochromatic light sources, black body radiation, ultraviolet and infrared radiation sources, etc.
8. Color.
    An outline of the physical properties of color, contrast, complementary colors, etc.
9. Optical Filters.
    Fairly complete coverage is given optical filters, including a discussion of transmission, absorption and reflection properties, polarizing filters, and attenuation of radiation.

Part II is composed of twenty sections as follows:

10. Protective Devices.
    Uses of photoelectric units as industrial safeguards such as fire prevention, detection of noxious gases, power presses, etc.
11. Production Control.
    Uses of photoelectric devices in textile, painting, manufacture of steel, testing.
12. Assembly Control.
13. Luminescence.
    Industrial uses in thermography, fluoroscopy, infrared image converters, etc.
14. Chemical Industry.
    The chemical industry uses such as ultraviolet and X-ray absorption analysis, automatic titration, etc.
15. Combustion Control.
    Control of fuel, flue gases and flames.
16. Temperature Control.
    Thermostatic control systems, low temperature control, measurement of high frequency energy.
17. Mining.
    Detection of fire-damp, dust in mines, and smoke.
18. Inspection of Mass-Produced Articles.
    These devices may be used in statistical quality control, for detecting flaws or impurities, gauging, etc.

Other applications include: 19. Colorimetry; 20. Step Control of a Productive Process; 21. Limit Switches; 22. Level Indicators; 23. Counting Devices; 24. Synchronizers; 25. Door Openers; 26. Timing Devices; 27. Relays; 28. Recorders; 29. Installation, Maintenance and Servicing.

Although covering the same field as Zworykin's *Photoelectricity*, this book is more thorough and complete. Both theory and practical devices are well outlined, analyzing the advantages and disadvantages of each type of photoelectric device. It is recommended as a laboratory reference book on the subject of photoelectric devices and their applications.

FREDERICK KOURY
Sylvania Elec. Products, Inc.
Salem, Mass.

Control Engineer's Handbook, ed. by J. G. Truxal

Published (1958) by McGraw-Hill Book Co., Inc. 330 W. 42 St., New York 36, N. Y. 1048 pages+75 index pages+xiii pages. 1145 figures. 6×9. $18.50.

In recent years the systems approach to problems has been elevated to primary significance. In this process the importance of available components and their characteristics has sometimes gotten less emphasis than desirable. A large number of books are available on control systems theory, much fewer on the nature and characteristics of components. It is this void that the *Control Engineer's Handbook* tends to fill and indeed fills quite well.

After covering the elements of control systems and analysis in a rather condensed fashion, the book concentrates on the description and analysis of control components. A desirable way of doing this is to: (1) discuss the underlying principles of the design and use of the component; (2) describe available components and their design; (3) summarize the theoretical tools used to describe these components; and (4) demonstrate the analysis and design of systems involving such components. In some of the sections this recipe is followed with excellent success; in other cases the treatment is not as complete. Perhaps the best example of an excellent treatment is the section on hydraulic controls (Section 15). But even where some aspects enumerated above may be weak or absent, the information present is most valuable. In certain cases this book appears to be the only comprehensive source of the subject from the point of view of the control engineer. The sections on magnetic amplifiers (Section 7), mechanical components (Section 13), clutches and brakes (Section 14), and signal transducer (Section 17) will prove to be invaluable, if not sole, sources for the practical control engineer.

The effort of condensing the analytical methodology has naturally resulted in some brief and one-sided coverage. For example, nonlinear system analysis in Section 2 covers numerical computations in one page, concentrating on one specific numerical method. Another example of such an omission is the treatment of sampled data system analysis in which digital computers are not mentioned. Fortunately, more effort is devoted to design techniques (Section 3) which is extensive and practical. In Section 4, specialized design techniques, an excellent summary of network synthesis is presented; yet this is a field which has been well covered in the literature. The relation of network synthesis to control design problems could be more heavily emphasized. In the same section the use of signal flow graphs is presented and constitutes a welcome addition to control theory. The examples, however, could have been extended to the analysis of whole systems in addition to circuit analysis. Also in this section the treatment of random functions and statistical methods as they apply to control systems is good but somewhat brief. A more extended treatment would have compensated for the relative dearth of appropriate text books.

The most complex components in control systems are computers which are dealt with in Section 5. The role of electronic analog computers in simulation and analysis of control problems is extremely well treated. But practically no mention is made of mechanical analog computers and of the role of analog computers as part of control systems. The treatment of digital computers is more balanced, and covers both simulation and control. This section could be correlated with sampled data theory by describing z-transforms of computer programs and by analyzing specific systems using digital computers.

As the preface mentions, the purpose of the handbook was not to cover every possible component but to give a thorough treatment of the approaches to their design and utilization. As an example solenoids are mentioned only incidentally and although relay characteristics (Section 10) are covered excellently no drawing or photograph of that component is shown. But in most cases the control components are thoroughly covered and copious design information supplied. This handbook then becomes an excellent collection of useful and unified information on a variety of important topics ranging from amplifiers through transistors, power supplies, electromechanical and mechanical items to hydraulic and pneumatic controls.

Altogether the book is a very welcome addition to the library of the control engineer and fills a real need which was begging to be filled in the control field.

J. M. SALZER
The Magnavox Research Labs.
Los Angeles 64, Calif.

Van Nostrand's Scientific Encyclopedia, 3rd ed.

Published (1958) by D. Van Nostrand Co., Inc., 257 Fourth Ave., N. Y. 10, N. Y. 1839 pages+vii pages. 1400 figures. 9×11¼. $30.00.

This book on the physical sciences, mathematics, engineering, and medicine covers twenty-three major subjects: chemistry, nuclear science and engineering, guided missiles, metallurgy, chemical engineering, physics, electrical engineering, mechanical engineering, electronics, astronomy, navigation, meteorology, photography, aeronautics, civil engineering, statistics, mathematics, geology, mineralogy, radio and television, botany, zoology, and medicine. In an attempt to obtain unity, the publishers assigned to one authority the responsibility for the coverage of each field.

The encyclopedia defines and explains about 15,000 terms, which are arranged alphabetically. A useful feature is a cross referencing system that puts key words of the explanations in bold-face type. Each cross reference is itself explained and described in its alphabetical position. Thus, the original expository material is considerably amplified.

Any publication that is represented as an encyclopedia immediately becomes open to attack by critics who are piqued at the audacious implication of all-inclusiveness conveyed by such a work. For this reason most reviewers find it very difficult to be objective and fair when evaluating an encyclopedic work.

For this review a formula was sought for averaging out individual prejudices so that a valid opinion could be presented. The biological sciences were ignored since these are of secondary interest to the radio engineer. For the categories representing the physical sciences and engineering, workers in those areas were interviewed. Fortunately, it was possible to reach individuals in a wide variety of scientific pursuits, since they were conveniently found in the organization in which this reviewer is employed. Each individual was requested to sample a representative list of terms of his own choosing. When judging the adequacy with which each term was covered, he was requested to weigh the following:

a. The completeness of the definition.

b. The detail of definition that one should rightfully expect in an encyclopedic work of this size and scope.

c. The usefulness and adequateness of the definitions to persons in the same field as well as to those in other scientific fields.

This reviewer must admit that he commenced this survey with the preconceived idea that the results of the poll would not favor this book. With remarkably few exceptions this encyclopedia was found to be very satisfactory. Some of the entries were more comprehensive than one might expect considering the multiplicity of fields covered. Most of the persons who participated in this review commended the excellence of this encyclopedia and only two expressed any doubt as to its value.

Any work of this type is bound to have a few weaknesses as exemplified by the omissions that were uncovered by the survey. It would serve little purpose in this critical review to point out those omissions, since they were an insignificant per cent of the terms searched.

The flaws must be weighed against the merits of the book. This has been done, and *Van Nostrand's Scientific Encyclopedia*, 3rd edition, has not been found wanting. While the purchase price of $30.00 might seriously strain the budget of an individual, certainly the benefit that is to be derived from this work makes it a worthwhile investment for libraries and organizations.

Gustave Shapiro
National Bureau of Standards
Washington 25, D. C.

Recent Books

Frohlich, H., *Theory of Dielectrics*, 2nd ed. (identical to the first edition except for an addendum containing three paragraphs.) Oxford University Press, 114 Fifth Ave., N. Y. 11, N. Y. $4.80.

Jones, D. D., and Hilbourne, R. A., *Transistor A.F. Amplifiers.* Philosophical Library, Inc., 15 E. 40 St., N. Y. 16, N. Y. $6.00.

Landee, R. W., Davis, D. C., and Albrecht, A. P., *Electronic Designers' Handbook.* McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. $16.50.

Murphy, G. J., *Basic Automatic Control Theory.* D. Van Nostrand Co., Inc., 257 Fourth Ave., N. Y. 10, N. Y. $10.75.

Peck, L. G., and Hazelwood, R. N., *Finite Queuing Tables.* John Wiley & Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. $8.50.

Perrine, J. O., *Physics and Mathematics in Electrical Communication.* John F. Rider, Inc., 116 W. 14th St., N. Y. 11, N. Y. $7.50.

Platt, Sidney, *Industrial Control Circuits.* John F. Rider, Inc., 116 W. 14th St., N. Y. 11, N. Y. $3.90.

Proceedings of the EIA Conference on Maintainability of Electronic Equipment. Engineering Publishers, GPO Box 1151, N. Y. 1, N. Y. or Interscience Publishers, 250 Fifth Ave., N. Y. 1, N. Y. $5.00.

Proceedings of the Fourth Annual Computer Applications Symposium. Armour Research Foundation of Illinois Institute of Technology, 10 W. 35th St., Chicago 16, Ill. $3.00.

Proceedings of the 1957 National Electronics Conference—Vol. 13. R. E. Bard, National Electronics Conference Headquarters, 84 E. Randolph, Chicago, Ill. $7.50.

Proceedings of the XIIth General Assembly, Volume XI, Part 1, Commission I on Radio Measurements and Standards. Secretary-General of U.R.S.I., 7, Place Emile Danco, Uccle-Brussels, Belgium. $2.00.

Richmond, A. E., *Calculus for Electronics.* McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. $8.25.

Riordan, John, *An Introduction to Combinatorial Analysis.* John Wiley & Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. $8.50.

Schure, A., *Impedance Matching.* John F. Rider, Inc., 116 W. 14 St., N. Y. 11, N. Y. $2.90.

Schure, A., *Vacuum Tube Rectifiers.* John F. Rider, Inc., 116 W. 14th St., N. Y. 11, N. Y. $1.50.

The Direction of Research Establishments. Proceedings of a symposium held in 1956 in England. Philosophical Library, Inc., 15 E. 40 St., N. Y. 16, N. Y. $12.00.

Timbie, W. H., *Basic Electricity for Communications*, 2nd ed. Revised by F. J. Ricker. John Wiley & Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. $6.25.

Abstracts of IRE Transactions

These issues of TRANSACTIONS have recently been published, and are now available from the Institute of Radio Engineers, Inc., 1 East 79 Street, New York 21, N. Y., at the prices indicated. The contents of each issue and, where available, abstracts of technical papers are given on the following pages.

Sponsoring Group	Publication	Group Members	IRE Members	Non-Members*
Broadcast & TV Receivers	Vol. BTR-4, No. 3	$1.20	$1.80	$3.60
Component Parts	Vol. CP-5, No. 2	1.65	2.50	4.95
Education	Vol. E-1, No. 2	1.10	1.65	3.30
Industrial Electronics	PGIE-6	2.00	3.00	6.00
Nuclear Science	Vol. NS-5, No. 1	.80	1.20	2.40
Telemetry & Remote Control	Vol. TRC-4, No. 1	.80	1.20	2.40

** Public libraries and colleges may purchase copies at IRE Member rates*

Broadcast & TV Receivers

Vol. BTR-4, No. 3, June, 1958

Gilbert E. Gustafson (p. 1)

Look for More Troubles (p. 2)

Minutes of the Meeting of the Administrative Committee of the IRE Professional Group on Broadcast and Television Receivers (p. 3)

Chapter News Reports (p. 7)

Call for Papers for Radio Fall Meeting (p. 9)

Characteristics and Applications of Low Impedance Diodes Used as Voltage Variable Capacitors—W. F. Palmer and D. H. Rice (p. 10)

The use of germanium VLI diodes as voltage sensitive capacitors has been investigated. Data concerning the variation of diode capacitance with bias voltage is presented and circuit requirements for resonant circuits tuned with variable capacitance diodes are discussed.

Formulae and curves for Q and frequency control sensitivity are developed and discussed in view of VLI diode characteristics.

Two basic modes of diode operation are possible:

(a) Self-bias operation
(b) External-bias operation

Unexpectedly large values of diode capacitance have been encountered in self-bias operation and are explained. Large and small signal operations are also discussed.

Practical circuits for television fine tuning and FM automatic frequency control are presented and possible television automatic frequency control is discussed.

Transitorized TV Horizontal Deflection and High Voltage System—G. Schiess and W. Palmer (p. 19)

Design considerations for transistorized television horizontal-deflection circuits are given.

Deflection volt-ampere requirements for various picture tube sizes are tabulated and compared to the deflection power capabilities of presently available transistors.

An experimental deflection circuit for a small screen picture tube (8DP4) is described, consisting of transistor phase detector, blocking oscillator, driver, and transistor output stage.

Objective specifications are given for horizontal deflection transistors for use with picture tubes of various screen sizes and deflection angles.

Transistorized Sound Section for TV Receivers—George Schiess and William Palmer (p. 36)

Two circuits for transistorized sound sections for use in hybrid or all-transistor TV receivers are described. Both circuits consist of transistor sound i-f amplifier, ratio detector and transistor audio amplifier. Performance data are given for both circuits.

Calendar of Coming Events and Authors' Deadlines (p. 42)

1957 Award of the PGBTR (p. 44)

Component Parts

Vol. CP-5, No. 2, June, 1958

Information for Authors (p. 71)

Recent Advances in the Solid-State Electrolytic Capacitor—A. V. Fraioli (p. 72)

The tremendous interest in the solid-state capacitor is due to the combination of superior technical characteristics with very small size and large "bulk" capacity. Present literature shows 35 vdc and 85°C voltage and temperature limitations.

Through the analysis of units made to operate at the extended limits of 100 vdc and 150°C, a model has been proposed which serves to explain four sets of anomalous and apparently unrelated electrical characteristics found in this type of unit.

Some Problems Associated with the Charging of Dry Batteries—P. H. Adams (p. 76)

The effects of the periodic application of a reverse emf to dry batteries, with the object of increasing their service life, are discussed and the optimum conditions to minimize the possibility of damage to both flat and round cells are laid down. The application of this process in ac battery portable radio receivers is examined and it is shown that the extent to which battery service life is likely to be increased is dependent on the conditions of use of the receiver in question.

Conductive Ceramics—Z. A. Post and P. E. Ritt (p. 81)

This paper describes a representative selection of materials from the general class known as conductive ceramics. Specifically, the materials discussed are tin oxide, zirconium oxide, silicon carbide, and molybdenum disilicide. A table of some of the more pertinent physical, thermal and electrical properties of each material is included. Some of the present applications of the materials are discussed and other uses are proposed. A graph of the specific resistivity of tin oxide vs absolute temperature is given, and a figure shows the effect of impurities on the specific resistivity of tin oxide vs absolute temperature. A discussion of the results of a preliminary investigation to determine the feasibility of electroplating various metals on the surface of tin oxide is presented.

The Symmetrical Transfer Characteristics of the Narrow-Bandwidth Four-Crystal Lattice Filter—T. R. O'Meara (p. 84)

The conventional four-crystal lattice filter is analyzed, without recourse to image parameter theory, in order to obtain an (approximate) expression for a general symmetrical insertion-loss characteristic. The resulting expression is given as an equivalent low-pass transfer function which is the ratio of two polynominials of the second degree in complex frequency. These in turn have coefficients which are functions of three parameters:

1) shunt capacitance ratio;
2) fractional-bandwidth, crystal-Q products;
3) fractional stagger of the inner critical frequencies of the crystal.

Numerous curves illustrate the effect on the insertion-loss characteristic of the three design parameters.

Where comparision is possible, the approximate equations reached in this paper are shown to agree with the corresponding approximate image parameter equations of Kosowsky. Also, a variety of responses are shown to result which were not discovered by previous image parameter techniques.

The approximations involved are equivalent to ignoring critical frequencies of the impedance elements (and hence of the transfer function) when these are far removed from the filter center frequency. Thus the representation is only valid near the filter center frequency. However, the error involved in the approximation is typically less than 0.1 db to the 40-db attenuation points, with narrow-band filters.

Transient Response of Phosphors—G. I. Cohn and H. M. Musal (p. 90)

The transient behavior of cathode-ray tube phosphors is of considerable interest in many applications, such as the improvement of the signal-to-noise ratio in radars. Although material appears in the literature concerning the decay characteristics a short time after the excitation is switched off, very little appears regarding the buildup characteristics or the decay characteristics immediately following removal of the excitation. The analysis of a phosphor model which covers the entire buildup and decay range is presented in this paper. The analysis shows that under certain conditions the transient behavior of phosphor brightness buildup and decay can be accurately expressed in a relatively simple form during the excitation period and immediately after the excitation is removed. The transient behavior and time constants involved are determined by the number of different types of imperfection centers present and their excitation and decay probability time densities.

Prediction of Temperatures in Forced-Convection Cooled Electronic Equipment—Lawrence Fried (p. 102)

In electronic equipment, the life, reliability, and operating characteristics of component parts (tubes, resistors, capacitors, motors, etc.) to a large extent are determined by temperature conditions within the parts. In practical cases, these internal conditions are best represented by one or more temperatures on the surface of each part. In special cases, with precautions, even large items such as pressurized equipment may be regarded as component parts, and their internal temperature conditions may be related to case temperatures.

There is great need to be able to predict the surface temperatures of component parts without performing an endless series of tests, the results of which are ambiguous in many instances.

The analysis presented is limited to prediction of surface temperatures of component parts which are cooled primarily by forced convection. In this case, conductive and radiative cooling would be relatively small. This limitation is not a major one, however, because it is expected that most electronic equipment, especially airborne equipment, will be forced-convection cooled. The heat dissipated by component parts by means other than convection will often appear at some other surface and be removed by convection.

Evaluating the Thermal Stability and Radiation Resistance of Silicone Dielectrics—D. F. Christensen (p. 107)

This paper, directed toward the designers of electronic equipment, deals with the aspects of thermal stability and radiation resistance of silicone dielectrics. Information is included which indicates how designers can utilize the maximum thermal stability and radiation resistance inherent in the silicone molecule. It points out that the useful life of silicone electrical insulation subjected to these environments is largely dependent upon physical rather than electrical property changes.

Contributors (p. 116)

Education

Vol. E-1, No. 2, June, 1958

The Laboratory (p. 33)

Whither Electrical Engineering Education—Samuel Seely (p. 34)

Changes have been occurring in the character of the present-day engineering product which require a review of the education for such engineering. A number of studies and reports have been made which seek to assess the needs and to suggest ideas for meeting the real challenge that exists. A separate study has been conducted by a group at the Case Institute of Technology along these same lines. This paper discusses the general educational problems and the broad philosphy which have been established to guide our subsequent curriculum development. The result is the need for a complete reappraisal of the existing curricula, with a degree of depth and integration along subject matter far beyond anything that has heretofore been attempted.

A New Technique of Education—Simon Ramo (p. 37)

The rapid advance of science and technology in today's world threatens to heighten, rather than minimize, the coming crisis in education. This paper advocates that the technological advances now possible must include advances also in the method of education. Those now engaged in modern engineering and science must apply their ingenuity and resources to major creative efforts in the art of teaching. As with all other intellectual tasks in the coming period, the educational process must also be visualized as a "man-machine" process. The brain and sense of the human teacher must be extended by new engineering systems. This paper discusses specific examples, including feedback as a concept in automatic or semi-automatic lecturing, and stresses that by removing from the duties of the teacher those tasks which can be done as well or better by machines the teacher is elevated to those tasks requiring the superior intelligence and sensitivity of a trained human being.

A High-School Science Teacher Views Industry-Education Cooperation—T. D. Miner (p. 43)

Teachers actively engaged in the classrooms do not agree that today's science education is a failure. Schools are expressions of our culture, and their deficiences have much deeper roots than most current analysis recognize. Fundamental rather than superficial remedies are indicated. Industry, in its approach to education must recognize the central importance of the teacher himself as an expert in the job to be done, and try to adjust its efforts to the special conditions of the classroom. Certain of the steps now being taken by industry in the field of secondary education are noted, and suggestions for their improvement are offered. It is necessary to put intellectual interests in a favorable competitive position with respect to more glamorous teen-age activities, and a possible action in this direction is suggested.

Improvement of the economic and social status of the teaching profession would be the single most powerful development in bringing about better secondary education.

Teaching Aids for Laboratory Courses in Electrical Circuits and Electronics—Dale Rummer (p. 46)

As more and more material becomes relevant for laboratory work in the undergraduate curriculum in electrical engineering, it becomes increasingly important to find more efficient systems for setting up the equipment for laboratory experiments. Any such system should result in a neat, easily followed arrangement when assembled, should be flexible with respect to the experiments which can be performed, and should not result in stereotyped experiments.

This paper describes a system which has been evolved utilizing chassis upon which are mounted an array of banana jacks on three-quarter inch centers. Many different circuits can be assembled easily and quickly by plugging in components which are mounted on double banana plugs. Different chassis are arranged for different circuits such as a dual triode, single pentode, and push-pull power amplifier.

A Proposed "Automatic" Teaching Device—P. K. Weimer (p. 51)

Teaching devices capable of directing the study of a student in accordance with his individual needs and capabilities offer exciting possibilities for the schools of the future. An "automatic" teaching device is one which incorporates both the presentation of information and the testing of the student in a controlled feedback relationship. This paper presents the case for "automatic" teaching devices along with some proposals for the construction of such machines.

Crisis in Engineering Education—J. L. Stewart (p. 54)

It is contended that engineering education in the United States is and has always been backward and of low quality compared to that in other countries, particularly Russia. Consequent low quality raises serious questions regarding ability to compete with the Communist world.

Historical reasons for low quality are scrutinized as created by personality factors, financial matters, university policies, and federal policies. Significant differences between educators and practitioners in science and engineering are discussed. Specific practical proposals for action by federal and university agencies are given which can aid in reducing the serious shortage of well-trained engineers.

Contributors (p. 62)

Call for Letters to the Editor (p. 63)

Industrial Electronics

PGIE-6, May, 1958

(*Sixth Annual Industrial Electronics Symposium, Chicago, Ill., September 23–24, 1957*)

Message from the Publications Chairman (p. 2)

Transmission of Signal Data from High Speed Machines—E. S. Shepard (p. 3)

This paper deals with the development of a completely transistorized and encapsulated telemetering device capable of transmitting signal data from high-speed machines at speeds up to 54,000 rpm. The need for this type of telemetering arose from the simple fact that in many instances it was not convenient to install contacting devices of a permanent nature on certain types of turbine machinery and the like, due to space limitations and limitations in the maximum number of information channels.

The Inductosyn, Its Uses and Applications to Machine Control—J. L. Winget (p. 14)

Magnetic and Eddy Current Type Transducers for Use in Industrial Electronics—D. L. Elam (p. 29)

The characteristics of magnetic pickups are discussed with regard to practical application. The principles of operation are discussed briefly and the output voltages illustrated are taken under actual operating conditions at various speeds. The mechanical construction is covered in progressive steps. Various models for both low and high temperature applications are described.

A brief description of the principle of operation of the eddy current of proximity pickup is presented. The operating clearance range is given for various models. A description is given of the use of proximity pickups for counting work parts, for controlling feed and for initiating steps of operation in automated factories.

A Classification System for Measurement and Control—E. A. Keller (p. 38)

This paper describes a new approach for the classification of instruments for measurement and control.

Most of the previous classifications grouped the instruments according to their input and output characteristics, this new classification groups the instruments in terms of precision, dynamic behavior, shelf life, reliability of operation and purchase characteristics; such as cost, availability and volume. Each characteristic is specified by a decimal digit. Each digit number defines the performance of instruments for a specific quality within one order of magnitude.

This classification serves the systems engineers for a selection of compatible instruments to solve a specific problem of measurement or control.

A perforated card system is described permitting the selection of suitable instruments once the performance parameters for a specific problem has been established.

This classification was established for and with the cooperation of the Institute of Radio Engineers Subcommittee 10.3 on Industrial Electronics.

Rapid Volumetric Particle Size Analysis via Electronics—R. H. Berg (p. 46)

A basically new method for sub-sieve particle size analysis is described, with emphasis on the three dimensional nature of the measurement principle. Previous methods are comparatively reviewed, and the role played by electronics in enabling speed and accuracy of the new method is discussed.

By suspending particles in a conductive liquid and causing the suspension to flow through an immersed aperture with electrodes on either side, a series of voltage pulses is produced by the passages of individual particles. This series of pulses is electronically scaled and counted.

Various aspects of basic response, effects of coincident passages and calibration methods are discussed. Applications to a variety of materials are covered, with extension to different forms of data presentation for process control purposes. A number of specific examples are included.

Technique for Automatic Testing Electronic Components—V. W. Walter and S. W. Nelson (p. 53)

The technique for automatic testing of electronic components must be adapted to the requirements for each individual test program. This paper describes the methods employed in instrumenting two test programs. The first involves approximately 75,000 components of four types—resistors, diodes, transistors and capacitors—all being tested for an extended period under environmental and electrical load conditions. The second program, in contrast, describes the parameter measurements which have to be made on small quantities of semiconductor devices under nuclear radiation conditions.

Sonic Gas Analyzers and Their Industrial Uses—Dale I. Steele and Michael Kniazuk (p. 64)

The theory of operation is given for a gas analyzer utilizing the speed of sound for its operation. Sensitivities to traces of common gases in both air and helium are given. When suitable gas chromatography tubes are used with the analyzer, the quantitative analysis of some gas mixtures can be made using peak readings of the analyzer.

The Importance of High-Speed Voltage-to-Digital Translation Equipment for Industrial Data Control—J. F. LaFontaine (p. 68)

There are two basic arguments for the importance of high-speed voltage-to-digital translation equipment in an industrial control system. The first is that early voltage-to-digital conversion is an important step toward overall system reliability. Second, in a system where such equipment is used, in many applications system accuracy can be achieved only through the use of a high-speed converter. The first argument—the one for system reliability—is the more well-known of the two and is therefore considered only briefly. The second argument—system accuracy via high-speed digitization—is treated more fully and is exemplified by descriptions of specific applications of high-speed conversion devices.

Industrial Digital Systems—E. J. Otis (p. 73)

This paper discusses some of the basic reasons why digital equipment, rather than analog equipment, is preferable for logging and control systems. Characteristics of system components such as input multiplexer and digitizer, digital computer, and output devices are discussed as parts of an integrated, flexible, and reliable industrial data handling and control system. In discussing the functional role played by each of the above system components, broad design criteria are developed for their construction, and operation is demonstrated when controlled by a general-purpose digital computer.

An Electronic Approach to Sortation Control—R. W. Burtness (p. 80)

Various sorting operations, such as the sorting of sacked mail in terminals throughout the country, become very complex operations. In order to meet the requirements of complex systems such as these, a rugged, trouble free control system has been developed around computer techniques which give an extremely high degree of versatility. This article describes such a system which has been installed and is now operating in Philadelphia.

Photo-Electric Registration Control Systems—J. C. Frommer (p. 86)

Pulse-Width Control of Transistors—J. N. Van Scoyoc and R. W. Bull (p. 95)

Duty cycle, or pulse width, modulation can be used to advantage in transistor circuits where the desired output is a direct current or slowly varying voltage such as required in proportional control systems. For a prescribed transistor dissipation, several times greater load power can be controlled by this technique than with class A operation. Conversely, for a given load power, the transistor can be operated at lower dissipation and thus at higher temperatures than is permissible with conventional modes of operation. Circuits have been devised for several different types of load circuits and also for signal generation. Combination of the duty-cycle modulation generation and output circuits yields a unique direct current amplifier.

Obtaining Optimum Performance from a Magnetic Thermocouple Amplifier—W. E. Nesbitt (p. 101)

An instrument-type magnetic amplifier is operated with positive feedback to produce high gain. A negative feedback loop then trades this gain to achieve high effective input impedance. The resultant circuit presents negligible loading to a low-impedance thermocouple for use in temperature sensing and control equipments.

Two circuits are analyzed to determine conditions for optimum performance. One circuit has a single-stage amplifier; the other circuit uses a two-stage magnetic amplifier. Amplifier operation is analyzed and the behavior is predicted from the resulting equations. Predicted performance compares favorably with measured performance. The analytical results are used to optimize amplifier parameters and to anticipate the best amplifier for a given circuit.

A typical practical circuit is found to have an error of about 2 per cent when adjusted for an optimum gain of 262.

Design and Development of the Alinco Electronic Integrating System—G. W. Harrison and Harry Stern (p. 115)

The area beneath an analog curve (integral) is often a useful measurement in a host of different fields. However, resolution, inertia, response, and general performance of integrating devices has until now precluded their use in the study of transient and dynamic phenomena. The ALINCO Model 270 Integrating System is an all-electronic integrator invented by Charles M. Minke, ALINCO Production Manager. The heart of the system is a reactance tube oscillator tuned to 100 kc. Using suitable mixers, gates, and programming circuitry, the Model 270 displays elapsed time and total integral on decimal counter units with high resolution and linearity. Counting begins by preset signal level or by closing contacts, and stops by signal decay, preset time, or by closing contacts.

For transient phenomena, 100 milliseconds would provide 1000 counts for a readability of 0.1%. For long-term phenomena (over 100 seconds), provision has been made for hook-up of accessory counters to count beyond the capacity of the instrument.

In data reduction where analog signals or records are integrated, the Model 270 represents a fast, direct, and more accurate solution, especially where short rise times and rapidly changing amplitudes exist.

Industrial Measurements with X-Rays—J. E. Bigelow (p. 121)

A review is made of the application of x-ray photoelectric effect and scattering to diverse problems of measurement. The basis of operation of thickness and coating weight gages, spectrographic analyzers, diffraction apparatus, and inspection equipment will thereby be shown. It is recognized that many of the measurements now being made with X rays could be made in no other way; thus, it is especially hoped that a useful solution may be suggested for yet unsolved problems.

IRE Professional Group on Industrial Electronics Membership Directory (as of 1 April 1958) (p. 128)

Transducers for Machine Control—J. K. Snell (p. 6)

The paper presents a discussion of the types of analog transducers in use today for the automatic control of machine tools. Mentioned are comparator type transducers as used in tracer heads as well as direct measuring type transducers used for numerical positioning and numerical contouring controls. Types of transducers are classified and discussed from the standpoint of application and expected accuracy.

Nuclear Science

Vol. NS-5, No. 1, June, 1958

Simulation of Hot Channel Boiling in Water-Cooled Reactors—S. O. Johnson, N. J. Curlee, and J. V. Reihing (p. 1)

The problems encountered in a study of the transient response of a heat transfer system in which the coolant experiences a phase change are discussed. The differential equations which govern the system are presented. The analog computer circuit is developed from the equations and the peculiarities of the circuit are described. Analog results of a typical coolant flow transient are presented.

Instrumentation for Fast Neutron Time-of-Flight Studies—R. V. Smith (p. 10)

In connection with a continuing program of fundamental research concerning the scattering of fast neutrons, instrumentation has been developed for measuring the energies of 1-4 mev neutrons by means of their flight time over a one-meter path. Some problems involved in measuring the resultant 30-70 mμsec time intervals with an accuracy of a few per cent are discussed, together with the limitations imposed by intensity considerations, presently available photomultipliers, and known electronic recording techniques. Some results are given showing the spectra of neutrons scattered from a primary energy of 4.3 mev by zirconium, carbon, nickel, aluminum, and chromium.

On the Measurement of Transit Time Dispersion in Multiplier Phototubes—M. H. Greenblatt (p. 13)

In the use of a multiplier phototube to measure short time intervals, the accuracy of the measurement is limited by the statistical deviations in the output pulse from the phototube. These deviations arise from variations in the electron transit time in the phototube. This paper reports a technique by which the transit time dispersion in the tube structure can be measured. A beam of electrons is deflected through an aperture onto the first dynode of the photomultiplier by an rf sweep voltage. The output pulse resulting is examined using the sweep voltage as a time base. Values of the order of 1 mμsec were obtained using three commercial type photomultiplier tubes.

Technique and Measurement of Radiation Background in Albuquerque, New Mexico, During and After the Teapot Series—H. H. Sander and T. B. Cook, Jr. (p. 17)

Radiation background intensity has been monitored in Albuquerque, New Mexico, on a continuous, 24-hour basis since February 1, 1955. This paper describes the techniques used in the measurements. As an example, the increase in total dose received in Albuquerque due to the Teapot tests (atomic test series in Nevada, spring of 1955), over what the dose would have been had there been no tests, is determined to be 4.5 milliroentgens (mr).

Telemetry & Remote Control

Vol. TRC-4, No. 1, June, 1958

The Chairman's Message (p. 1)

A Survey of Progress Reported in 1956 and 1957 in Telemetry and Remote Control—F. E. Rock (p. 2)

Progress in the fields of telemetry and remote control reported during 1956 and 1957 is summarized under the headings: data processing, data storage, digital transmission equipment, millivolt telemeter equipment, multiplexing methods and equipment, radio transmission and systems, remote control, theory and analysis, transducers, and transistorized telemeter equipment.

Correction (p. 9)

A Bibliography of Telemetry—M. V. Kiebert (p. 10)

Space Ship Telemetry—H. Scharla-Nielsen (p. 20)

Application of the Phase-Locked Loop to Telemetry as a Discriminator or Tracking Filter—C. E. Gilchriest (p. 36)

This paper studies a system of FM detection suggested by work done in optimum-demodulation theory, and a summary of the problems of ordinary discriminators is made so that possible improvement may be demonstrated readily. This summary points out an important defect of FM discriminators which affects the data accuracy of the telemeter but which is rarely recognized. The system study deals with generalized optimum filtering for transient signals applicable to commutated signals and operators such as discrimination. The solution for particular applications with respect to the phase-locked loop or optimum-demodulation system is offered. With these applications available, noise and transient signals are studied to see how the system fits the practical system. Normalized charts are made which may be applied to any standard telemetering channel that may be designed. A comparison of this system with ordinary discriminators shows a large threshold improvement and a reduction in over-all system error. Graphs of the comparison of these effects are also included. Heuristic suggestions of application are offered for further study.

Abstracts and References

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research, London, England, and Published by Arrangement with that Department and the *Electronic and Radio Engineer*, incorporating *Wireless Engineer*, London, England

NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.

The Index to the Abstracts and References published in the PROC. IRE from February, 1957 through January, 1958 is published by the PROC. IRE, May, 1958, Part II. It is also published by *Electronic and Radio Engineer*, incorporating *Wireless Engineer*, and included in the March, 1958 issue of that journal. Included with the Index is a selected list of journals scanned for abstracting with publishers' addresses.

Acoustics and Audio Frequencies...... 1556
Antennas and Transmission Lines..... 1557
Automatic Computers................ 1557
Circuits and Circuit Elements......... 1558
General Physics..................... 1560
Geophysical and Extraterrestrial Phenomena......................... 1562
Location and Aids to Navigation...... 1562
Materials and Subsidiary Techniques.. 1562
Mathematics........................ 1566
Measurements and Test Gear........ 1566
Other Applications of Radio and Electronics.......................... 1566
Propagation of Waves............... 1567
Reception.......................... 1567
Stations and Communication Systems.. 1567
Subsidiary Apparatus................ 1568
Television and Phototelegraphy....... 1569
Transmission....................... 1569
Tubes and Thermionics.............. 1569

The number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number and is not to be confused with the Decimal Classification used by the United States National Bureau of Standards. The number in heavy type at the top right is the serial number of the Abstract. D.C. numbers marked with a dagger (†) must be regarded as provisional.

ACOUSTICS AND AUDIO FREQUENCIES

534.2 **1942**

The Scattering of Sound Waves in Inhomogeneous Waveguides—A. D. Lapin. (*Doklady. Akad. Nauk S.S.S.R.*, vol. 118, pp. 55–58; January 1, 1958.) Mathematical analysis for a waveguide filled with an inhomogeneous medium which has an average refractive index of about unity. Waveguides with rough interior walls are also examined. See also 3002 of 1957 (Isakovich).

534.232-14-8:534.133 **1943**

Amplitude of a Quartz Plate Vibrating in Liquids—S. Parthasarathy and Harkrishan Singh. (*Nature, London*, vol. 181, p. 260; January 25, 1958.) The amplitude of vibration of a quartz crystal plate in various liquids calculated according to Vigoureux's formula is compared with the amplitude of the resulting sound wave determined experimentally by a calorimetric method. See 1602 of 1956 (Parthasarathy and Narasimhan).

534.41:621.372.543.2 **1944**

Active, Adjustable Audio Band-Pass Filter—J. R. Macdonald. (*J. Acoust. Soc. Amer.*, vol. 29, pp. 1348–1356; December, 1957.) A filter having seventh-order Butterworth attenuation characteristics (42 db/octave slopes) is described. Six miniature double triodes and no inductors are used.

534.612:061.3 **1945**

Sound Level Meter Symposium—(*J. Acoust. Soc. Amer.*, vol. 29, pp. 1330–1341; December, 1957.) A summary is given of 10 papers read at a symposium held by the Acoustical Society of America in New York, May 23–25, 1957, in connection with Committee Z24-W-18 of the American Standards Association.

534.75 **1946**

Comparison of the Auditory Threshold as Measured by Individual Pure Tone and by Békésy Audiometry—W. Burns and R. Hinchcliffe. (*J. Acoust. Soc. Amer.*, vol. 29, pp. 1274–1277; December, 1957.)

534.75 **1947**

Threshold of Hearing and Equal-Loudness Relations for Pure Tones, and the Loudness Function—D. W. Robinson and R. S. Dadson. (*J. Acoust. Soc. Amer.*, vol. 29, pp. 1284–1288; December, 1957.) "In connection with standards for audiometry, measurements have been made of the threshold of hearing for pure tones by earphone listening, and these have since been extended to the case of listening in free field. Latterly a redetermination of the equal-loudness relations for pure tones has been completed aimed at resolving discrepancies between former determinations and providing an improved basis for the establishment of a standard set of contours. These results apply to a large team of otologically normal observers, and cover the range from 25–15,000 cps and up to 130 db in sound pressure level."

534.75 **1948**

Further Observations on Pitch associated with a Time Difference between Two Pulse Trains—W. R. Thurlow. (*J. Acoust. Soc. Amer.*, vol. 29, pp. 1310–1311; December, 1957.) Changing the time separation between two trains of filtered pulses, each at the same basic repetition rate, makes it evident that there is a pitch which is correlated with the magnitude of the time separation. See also 1855 of 1955 (Thurlow and Small).

534.76 **1949**

An Unexpected Effect in Sound Localization—D. H. Holding and J. P. Dennis. (*Nature, London*, vol. 180, pp. 1471–1472; December 28, 1957.) Tests at 1 kc show that sound localization by human subjects is improved by the wearing of a light cloth cap.

534.78 **1950**

Further Test of the Constant-Ratio Rule in Speech Communication—F. R. Clarke and C. D. Anderson. (*J. Acoust. Soc. Amer.*, vol. 29, pp. 1318–1320; December, 1957.) "The use of the constant-ratio rule to predict the confusion matrices for each of two five-item subsets given the confusion matrix for a ten-item master set is tested with naive subjects." See also 10 of 1958 (Clarke).

534.78 **1951**

Effects of Ambient Noise on Speaker Intelligibility for Words and Phrases—J. J. Dreher and J. J. O'Neill. (*J. Acoust. Soc. Amer.*, vol. 29, pp. 1320–1323; December, 1957.) Report of experiments based on a "voice-reflex" effect whereby a speaker with normal hearing unconsciously raises his voice and changes the characteristics of his speech to compensate for the level of noise in which he is speaking.

534.78 **1952**

Effect of Noise and Filtering on Speech Intelligibility at High Levels—I. Pollack and J. M. Pickett. (*J. Acoust. Soc. Amer.*, vol. 29, pp. 1328–1329; December, 1957.) The effects of a high level of background noise on intelligibility are compared with the effects of filtering.

534.78:621.39 **1953**

Signal Theory in Speech Transmission—E. E. David, Jr. (IRE TRANS. ON CIRCUIT THEORY, vol. CT-3, pp. 232–244; December, 1956. Abstract, PROC. IRE, vol. 45, pp. 716–717; May, 1957.)

534.78:621.395.623.54 **1954**

Speech Communication at High Noise Levels: the Roles of a Noise-Operated Automatic Gain Control System and Hearing Protection—I. Pollack. (*J. Acoust. Soc. Amer.*, vol. 29, pp. 1324–1327; December, 1957.) Two aids for hearing conservation, a noise-operated automatic gain control system and an insert ear protection, were evaluated in terms of their effect upon speech intelligibility. At high noise levels, these aids not only do not interfere with the speech intelligibility, they may substantially improve speech intelligibility while affording hearing protection.

534.78:621.395.625.3 **1955**

Intelligibility Measurements on Transmission Systems using German Logatoms Recorded on Magnetic Tape—W. Wisch. (*Nachrtech. Z.*, vol. 7, pp. 342–345; August, 1957.) A method of forming German logatoms is described. The use of tape recordings for subjective tests appears to be advantageous.

534.78:681.188:8.03 **1956**

Vowel Recognition in Clipped Speech—R. Ahmed. (*Nature, London*, vol. 181, p. 210; January 18, 1958.) In the course of work on speech-input devices for a translation machine a pulse count analysis has been made of vowel sounds in clipped speech. The consistency of the results is illustrated.

34.84 1957
Acoustical Field at Normal Modes in
ooms—T. S. Korn and R. Van de Plas. (*J.*
coust. Soc. Amer., vol. 29, pp. 1267–1270;
ecember, 1957.) "The physical form of the
coustical field at normal complex modes in
ooms can be represented as a set of elementary
urvilinear ducts, each carrying a single sta-
onary wave, satisfying individually the
oundary conditions at the walls. In spite of the
ifferences in their lengths, all the ducts
esonate at the same nominal frequency."

34.844/.845 1958
Design and Performance of a New Rever-
eration Room at Armour Research Founda-
ion, Chicago, Illinois—D. R. McAuliffe.
J. Acoust. Soc. Amer., vol. 29, pp. 1270–1273;
ecember, 1957.) The room has a volume of
pproximately 3000 ft^3 and a reverberation
ime of about 5 seconds. The four walls and
eiling of the room have been splayed. Meas-
rements indicate that the room has a rela-
ively uniform reverberation time with respect
o frequency.

34.88 1959
Analysis of a Multiple-Receiver Correla-
ion System—M. J. Jacobson. (*J. Acoust. Soc.*
mer., vol. 29, pp. 1342–1347; December,
957.) A theoretical study is made of an acous-
ic receiving system consisting of two arrays
f omnidirectional receivers and one corre-
ator.

21.395.614:546.431.824+31 1960
Laboratory Standard Ceramic Microphone
–W. Newitt. (*J. Acoust. Soc. Amer.*, vol. 29,
p. 1356–1365; December, 1957.) Microphones
sing $BaTiO_3$ disk ceramics in conjunction
ith a split-tube diaphragm are adaptable for
se at high sound pressures, and for sound
easurements in liquids as well as in air. Sen-
itivities from −86 to −88 db referred to 1
olt per dyne/cm^2 were obtained and the fre-
uency response was uniform within ±1 db
rom 10 cps to 30 kc.

21.395.623.74 1961
Principles of Loudspeaker Design and
peration—J. Chernof. (IRE TRANS. ON
UDIO, vol. AU-5, pp. 117–127; September/Oc-
ober, 1957. Abstract, PROC. IRE, vol. 46,
. 800; April, 1958.)

21.395.625:621.317.76 1962
"Wow" and "Flutter"—Bennett and Currie.
See 2190.)

21.395.625.3:621.397.5 1963
Television Tape Recorder—(See 2244.)

21.395.625.3:621.397.5 1964
Television Recording on Magnetic Tape by
he Ampex Method—Braunmühl and Schmid-
auer. (See 2245.)

ANTENNAS AND TRANSMISSION LINES

21.315.212.029.63/.64 1965
Variations of Characteristic Impedance
long Short Coaxial Cables—J. Allison. (*Proc.*
EE, pt. C, vol. 105, pp. 169–176; March,
958.) The measured deviations from a har-
nonic series of the resonance frequencies of a
hort length of open or short-circuited cable are
sed to calculate the coefficients of a Fourier
eries describing the impedance variations
long the length of the cable.

21.372.2 1966
Outline of a Theory of Nonuniform Trans-
nission Lines—B. G. Kazansky. (*Proc. IEE*,
t. C, vol. 105, pp. 126–138; March, 1958.)
amilies of complex differential equations are
nalyzed and the corresponding two-parameter solution curves investigated. The relationship between singular points of the differential equations for the normalized impedance and the nonreflective impedances of the corresponding nonuniform line are established.

621.372.2:621.3.012 1967
Transformation of the Smith Chart through Lossless Junctions—H. V. Shurmer. (*Proc. IEE*, pt. C, vol. 105, pp. 177–182; March, 1958.) The relation between the Smith chart representations of the impedances on either side of a lossless junction is analyzed using complex variables. A chart is derived for transforming circles of constant voltage SWR relating to any plane on one side of the junction, into corresponding circles relating to the corresponding plane on the other side.

621.372.21:621.396.65.029.6 1968
Cable and Radio Links for the Microwave Range—O. Zinke. (*Nachrtech. Z.*, vol. 10, pp. 425–430; September, 1957.) A comparison of the suitability and cost of coaxial and waveguide transmission lines for the various frequency ranges used in radio links. The performance of single-wire lines in the range 30–3000 mc is discussed in detail. The alternatives examined are the plain wire (Sommerfeld), the dielectric coated (Goubau) straight line, and helical plain and coated lines.

621.372.8 1969
A Contribution to the Theory of Probes in Waveguides—L. Lewin. (*Proc. IEE*, pt. C, vol. 105, pp. 109–116; March, 1958.) The theory of a probe spanning a rectangular guide and fed by a coaxial line is analyzed in detail in two cases: a) the short-circuit case considering the probe both as a top-short-circuited antenna and also as a waveguide post terminated by the cable impedance; b) a top-loaded probe, terminated by means of a tuning plunger.

621.372.821:621.3.095 1970
Parallel-Plate Transmission Lines and Equivalent Radiators—A. B. Hillan. (*Electronic and Radio Engr.*, vol. 35, pp. 170–173; May, 1958.) It is shown that an infinite plane current sheet has no induction field, and that the radiated field is a faithful reproduction of the current density.

621.372.826+621.396.677 1971
Excitation of Surface Waves—B. Friedman and W. E. Williams. (*Proc. IEE*, pt. C, vol. 105, pp. 252–258; March, 1958.) "It is shown how to locate a dipole source above a dielectric surface so as either to produce as pure a surface wave as possible or to maximize the amount of energy carried by the surface wave."

621.372.837.3:621.318.134 1972
Some Applications of Ferrites to Microwave Switches, Phasers and Isolators—A. C. Brown, R. S. Cole, and W. N. Honeyman. (PROC. IRE, vol. 46, pp. 722–727; April, 1958.) A switch is described which is matched in both states, and also one which can be used at a high repetition rate. The scaling of isolator designs is examined.

621.372.85:537.226:621.315.612.4 1973
Vacuum Breakdown in Dielectric-Loaded Waveguides—G. B. Walker and E. L. Lewis. (*Nature, London*, vol. 181, pp. 38–39; January 4, 1958.) Experiments of the type reported earlier [see 2560 of 1957 (Shersby-Harvie *et al.*)] were continued with the aim of studying breakdown in TiO_2 dielectric disks. Lead borate enamel is found to be very effective in preventing breakdown.

621.372.85:621.318.134 1974
Cut-Off Phenomena in Transversely Magnetized Ferrites—R. F. Soohoo. (PROC. IRE, vol. 46, pp. 788–789; April, 1958.) The cut-off frequencies are determined for a rectangular waveguide loaded with a lossless ferrite slab, and are checked by experiment.

621.396.67.095.1 1975
Transmission between Aerials of Any Type—K. Baur. (*Frequenz*, vol. 11, pp. 308–312; October, 1957.) Summary of practical formulas for evaluating received power together with definitions of various antenna parameters, covering reception in linearly and elliptically polarized fields.

621.396.673 1976
The Effect of the Ground Constants, and of an Earth System, on the Performance of a Vertical Medium-Wave Aerial—G. D. Monteath. (*Proc. IEE*, pt. C, vol. 105, pp. 292–306; March, 1958.) The compensation theory is used to examine the effect of ground conductivity and of an earth system upon the input impedance, the ground-wave field strength for a given antenna current, and the vertical radiation pattern. If the effective height of the antenna exceeds 0.1λ, an earth system of 0.2λ radius is sufficient for ground of high conductivity and of 0.3–0.4λ radius if of low conductivity. The vertical radiation pattern is not materially affected by the earth system.

621.396.677.029.63 1977
The Design of Decimetre-Wave Wide-Band Directional Aerials with Extremely Small Reflection Coefficient—H. P. Wolff. (*Optik*, vol. 14, pp. 458–473; October, 1957.) Two designs of radiating elements for use at 2 kmc with a bandwidth amounting to 10 per cent of midband frequency and a reflection coefficient less than $2\frac{1}{2}$ per cent are considered. In one design a paraboloidal reflector 3 meters in diameter is fed from a full-wave dipole with the reflector feedback cancelled; in the other a half-wave dipole is fitted but the feedback of the paraboloid is used to match the impedance of the radiator to that of the feeder.

621.396.677.3 1978
A Simplified Derivation of the Fourier Coefficients for Tchebysheff Patterns—J. L. Brown, Jr. (*Proc. IEE*, pt. C, vol. 105, pp. 167–168; March, 1958.) An alternative derivation of Salzer's result (350 of 1957).

621.396.677.6:621.396.933.2 1979
Study of the Feasibility of Airborne H.F. Direction-Finding Antenna Systems—Carter. (See 2096.)

621.372.2 1980
Transmission-Line Theory [Book Review]—R. W. P. King. Publishers: McGraw-Hill Book Co., Inc., London, Eng. 509 pp.; 1955. (*Nature, London*, vol. 180, p. 1443; December 28, 1957.)

AUTOMATIC COMPUTERS

681.142 1981
Digital Codes in Data-Processing Systems—M. P. Atkinson. (*Trans. Soc. Instrum. Tech.*, vol. 9, pp. 124–130; December, 1957.) The design of digital coding systems including error-detecting and error-correcting codes is discussed.

681.142 1982
A New Cycle-Counting Instruction for a Three-Address Electronic Digital Computer—L. Lunelli. (*Ricerca sci.*, vol. 27, pp. 3381–3394; November, 1957.) See also 3757 of 1957 (Dadda).

681.142 1983
An Electrical Apparatus for Solving Polynomial Equations—H. Adler. (*Nachrtech. Z.*, vol. 7, pp. 335–342; August, 1957.) The analog equipment described can be used for solv-

ing equations of up to 8th degree with real coefficients.

681.142.:514 1984

Computation of Arc Tan$N$ for $-\infty<N<+\infty$ using an Electronic Computer—E. G. Kogbetliantz. (*IBM J. Res. Dev.*, vol. 2, pp. 43–53; January, 1958.)

681.142:538.221 1985

The Application of Square-Hysteresis-Loop Materials in Digital Computer Circuits—A. D. Holt. (*Electronic Eng.*, vol. 30, pp. 196–199; April, 1958.) "Theories and the practical design of shifting registers are explained. Core matrix storage systems are reviewed. A description is given of a store in which a shifting register is used to convert the parallel output into serial form; this register is also used during the writing process."

681.142:621.374.32 1986

A Decimal Product Accumulator—R. R. Hoge. (*J. Brit. IRE*, vol. 18, pp. 125–132; February, 1958. Discussion, p. 133.) Dekatrons enable the correlation between two series of numbers to be found if all terms are positive. Given pairs of numbers of two decimal digits each, the machine accumulates 100 products per minute.

681.142(410) 1987

British-Built Computers—(*Overseas Engr.*, vol. 31, pp. 167–173; December, 1957.) A review of digital and analog computers with details of specifications, special features, and applications.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.018.7:[621.314.6+621.375.2 1988

Analysis of Current Pulses—F. G. Heymann. (*Electronic and Radio Engr.*, vol. 35, pp. 165–167; May, 1958.) An approximate method of analysis used earlier (2439 of 1955) is extended to include nonlinear characteristics, and its application to a class-C amplifier circuit is described.

621.3.049.75:621.375.1 1989

Printed Circuits and High-Quality Amplifiers—(*Point to Point Telecommun.*, vol. 2, pp. 18–24; February, 1958.) Printed circuits are suited to equipment where standardization is essential. Inherent in this type of circuitry is improved performance; special production methods are needed to ensure reliability.

621.3.049.75:621.397.62:535.623 1990

Etched I.F. Amplifier Pares Colour TV Cost—Ruth. (See 2248.)

621.311.62:621.3.072.2 1991

Simple Variable-Voltage Power Supply—J. M. Macintosh. (*Short Wave Mag.*, vol. 15, pp. 568–571; January, 1958.) Design details of a circuit giving an output of 0–200 volts at currents up to 60 ma.

621.318.42:538.221:538.566 1992

Electromagnetic Fields in a Ferromagnetic Medium, with Particular Reference to Harmonic Distortion due to Hysteresis—V. G. Welsby. (*Proc. IEE.*, pt. C, vol. 105, pp. 218–229; March, 1958.) The frequency dependence of the third-order distortion factor of an inductor at low flux densities is studied theoretically. An analog method is described which enables the study to be extended experimentally to large flux densities and complex input waveforms.

621.318.5 1993

A Numerical-Graphical Method for Synthesizing Switching Circuits—A. H. Scheinman. (*Commun. & Electronics*, no. 34, pp. 687–689; January, 1958.) Economical circuit arrangements can be rapidly developed by systematic application of three simple rules to a numerical representation of a Boolean function. Simple examples are given.

621.318.57 1994

Minimum-Energy Triggering Signals—L. A. Beattie. (Proc. IRE, vol. 46, pp. 751–757; April, 1958.) The optimum signal is defined as that which produces a given current through, or a voltage across, a resistive output element at a given time, while requiring a minimum of energy from the generator. The solution of this problem is discussed and illustrated by a simple case.

621.318.57:621.314.7 1995

Controlled Saturation in Transistors and its Application in Trigger Circuit Design—N. F. Moody. (*Electronic Eng.*, vol. 30, pp. 121–127 and 200–204; March and April, 1958.) Carrier storage of charge in transistors has a maximum which is defined as controlled saturation; this depends only on the base current. This idea is used to develop a trigger circuit of good resolving time whose output terminal is able to handle heavy currents and presents a low impedance.

621.318.57:621.314.7 1996

Fast Transistor Relay—D. L. Anderson. (*Electronics*, vol. 31, p. 145; March 14, 1958.) Describes a push-pull switching circuit incorporating Zener diodes having a rise time of 50 μsec and capable of handling currents up to 10 a.

621.372.011.1 1997

Generalized Operators for the Approximate Steady-State Analysis of Linear and Nonlinear Circuits—A. J. O. Cruickshank. (*Proc. IEE*, pt. C, vol. 105, pp. 76–87; March, 1958.) The method is a periodic analog of the time-series technique by which waveforms are represented by an n-component operator giving values at each of n ordinates. A shift operator translates any waveform by $1/n$th of the appropriate sample period. For linear circuits the method is advantageous where the periodic input is known and a similar description of the output is required without recourse to Fourier analysis. For nonlinear circuits the output is obtained by a series of approximations applied to the steady-state condition.

621.372.012:621.391 1998

Signal Theory—W. H. Huggins. (IRE Trans. on Circuit Theory, vol. CT-3, pp. 210–216; December, 1956. Abstract, Proc. IRE, vol. 45, p. 716; May, 1957.)

621.372.012:621.391 1999

System Theory as an Extension of Circuit Theory—W. K. Linvill. (IRE Trans. on Circuit Theory, vol. CT-3, pp. 217–223; December, 1956. Abstract, Proc. IRE, vol. 45, p. 716; May, 1957.)

621.372.09 2000

Derivation of the Phase Characteristic from the Attenuation Curve in Minimum-Phase Systems—E. A. Graham. (*Alta Frequenza*, vol. 26, pp. 563–576; October, 1957.) The graphical method described is illustrated by numerical examples.

621.372.412:621.372.54 2001

Stable Crystal Filter is Parallel Resonant—J. C. Seddon. (*Electronics*, vol. 31, pp. 155–157; March 14, 1958.) A high-Q, unbalanced crystal circuit is similar to a parallel-tuned circuit with a low LC ratio over an appreciable frequency range. It is readily adaptable for use in FM oscillators, signal generators and variable-bandwidth filters.

621.372.413 2002

The Concept of Heterogeneous Surface Impedance and its Application to Cylindrical Cavity Resonators—A. E. Karbowiak. (*Proc. IEE*, pt. C, vol. 105, pp. 1–12; March, 1958.) Formulas are developed relating the Q-factor and the resonant frequency of a cavity to its dimensions and the Fourier components of the surface impedance function. The cases of circumferential and axial heterogeneity are analyzed in detail. In general, a unique value of surface impedance cannot apply to an unbounded periodic sheet unless the period is small compared with λ.

621.372.5 2003

Synthesis of Tchebycheff Impedance—Matching Networks, Filters and Interstages—G. L. Matthaei. (IRE Trans. on Circuit Theory, vol. CT-3, pp. 163–172; September, 1956. Abstract, Proc. IRE, vol. 45, p. 253; February, 1957.)

621.372.5 2004

Two Theorems Concerning Group Delay with Practical Application to Delay Correction—G. G. Gouriet. (*Proc. IEE*, pt. C, vol. 105, pp. 240–244; March, 1958.) "Two theorems are stated which enable properties of group delay to be expressed directly in terms of the transfer function of a linear transmission system. Examples are given to show how the results might be usefully applied to certain problems of delay correction."

621.372.5:621.374.3 2005

Linear Pulse-Forming Circuits—W. C. Gore and T. Larsen. (IRE Trans. on Circuit Theory, vol. CT-3, pp. 182–188; September, 1956. Abstract, Proc. IRE, vol. 45, p. 253; February, 1957.)

621.372.5:621.396.96 2006

Synthesis of Delay-Line Networks—D. A. Linden and B. D. Steinberg. (IRE Trans., on Aeronautical and Navigational Electronics, vol. ANE-4, pp. 34–39; March, 1957. Abstract, Proc. IRE, vol. 45, p. 1034; July, 1957.) Description of synthesis procedure for delay systems used in processing continuous-trace radar information.

621.372.54 2007

The Network Synthesis on the Insertion-Loss Basis—J. Zdunek. (*Proc. IEE*, pt. C, vol. 105, pp. 259–291; March, 1958.) Methods of synthesis of most important network functions are derived in terms of the steady-state network performance; realization procedures are explained and expressed in explicit formulas for direct application to the design of conventional ladder structures with an arbitrary number of branches. The symmetrical and the inverse-impedance low-pass networks are solved in detail.

621.372.54:621.318.4 2008

Exact Ladder Network Design using Low-Q Coils—L. Weinberg. (Proc. IRE, vol. 46, pp. 739–750; April, 1958.)

621.372.6 2009

Conditions for the Impedance and Admittance Matrices of n-Ports without Ideal Transformers—I. Cederbaum. (*Proc. IEE*, pt. C, vol. 105, pp. 245–251; March, 1958.)

621.372.6.012.8:621.396.822 2010

Equivalent Circuits of Noisy Networks—L. Young. (*Electronic Eng.*, vol. 30, pp. 205–207; April, 1958.) Equivalent circuits for a combination of amplifiers, attenuators, and terminations are presented and a new method for the precision measurement of noise figure is described.

621.372.622 2011

Small-Signal Heterodyne Mixers with Excessive Injection Amplitudes—J. F. Cline. *Commun. & Electronics*, no. 34, pp. 739–745;

January, 1958.) The theory of small-signal heterodyne mixers operating with very large injection potentials is described. The mixer properties investigated are the conversion transconductance, the relative amplitudes of the difference-frequency and injection-frequency components in the output, and the amplitude of the injection modulation-frequency component in the output in the case where the injection potential is amplitude-modulated to a small degree. A set of universal performance curves is obtained for mixers of a particular class chosen to illustrate the method.

621.373.421.13 2012

VXO-a Variable Crystal Oscillator—H. Shall. (*QST*, vol. 42, pp. 11–15; January 1958.) Description of a stable oscillator which covers the range 3500–4000 kc and uses six crystals.

621.373.431.1 2013

Flip-Flop Stability—T. G. Clark. (*Wireless World*, vol. 64, pp. 212–213; May, 1958.) Modifications to the circuit described earlier (716 of 1958), including the use of a different type of tube, do not affect its stability in respect to pulse duration.

621.373.444:621.314.7 2014

Transient Processes in a Trigger Circuit with a Transistor—N. I. Brodovich. (*Avtomat. i Telemekh.*, vol. 18, pp. 273–279; March, 1957.) Transient processes in a common-base circuit using a point-contact transistor are considered. Expressions for the currents are derived and the speed of operation of the circuit is estimated. Requirements are formulated for point-contact transistors to be used in high-speed trigger circuits. See also 2381 of 1957 (Kuz'min).

621.373.444:621.314.7 2015

High-Sensitivity Transistor Pulse Trigger Circuit—E. Zaglio. (*Nuovo Cimento*, vol. 6, pp. 512–515; September 1, 1957.) (In English.) A Ge diode and a differential negative resistance of high stability consisting of a transistor amplifier with positive feedback is used.

621.373.52 2016

Transistorized *RC* Phase-Shift Power Oscillator—L. J. Giacoletto. (IRE Trans. on Audio, vol. AU-5, pp. 59–62; May/June, 1957.) Data on the performance of a *RC* phase-shift circuit operating at frequencies around 1 kc are given.

621.375.1:621.396.822 2017

A Theorem concerning Noise Figures—A. G. Bose and S. D. Pezaris. (IRE Trans. on Circuit Theory, vol. CT-3, pp. 190–196; September, 1956. Abstract, Proc. IRE, vol. 45, p. 254; February, 1957.)

621.375.121.1 2018

Stagger-Tuned Band-Pass Amplifiers—Y. Peless. (*Electronic and Radio Eng.*, vol. 35, pp. 175–178; May, 1958.) A procedure is given for designing narrow-band amplifiers with specified gain and overshoot when either bandwidth or rise time is specified. Data are included for single-tuned cascades with up to five stages. See also 3774 of 1957 (Peless and Murakami).

621.375.126.016.35 2019

Stability and the Effects of Valve Input Conductance in Wide-Band I.F. Amplifiers—F. Carassa. (*Alta Frequenza*, vol. 26, pp. 550–562; October, 1957.) An analysis of the effects of small variations of circuit parameters and of tube input conductance on amplitude and group-delay response of double-tuned interstage amplifiers. See also 2368 of 1957.

621.375.13:621.376.23 2020

Some Studies on Delayed Feedback Circuits—H. Seki. (Proc. IRE, vol. 46, pp. 758–763; April, 1958.) By inserting delayed signals along with the main signal to be observed, an improvement in signal/noise ratio can be achieved. Other applications of this circuit are for producing artificial reverberation [see 3476 of 1955 (Axon *et al.*)], as a narrow-band filter, and as a short-time storage circuit.

621.375.2:621.317.725 2021

Bootstrapped Differential Amplifier with Reduced Common-Mode Effects—R. J. Blume. (*Rev. Sci. Instr.*, vol. 29, pp. 122–124; February 1958.) A common-mode signal of ±35 volts changes the differential gain of the circuit by 0.5 per cent or less. Full-scale deflection can be obtained on a 1-ma 1.5-kΩ recorder with 0.2-volt dc input.

621.375.2.029.3 2022

Push-Pull Audio Amplifier Theory—M. A. Melehy. (IRE Trans. on Audio, vol. AU-5, pp. 86–89; July/August, 1957.) A mathematical analysis is given applicable to all classes of operation of the push-pull amplifier assuming nonlinear tube characteristics.

621.375.2.029.3 2023

Two-Valve Pre-amplifier—C. Hardcastle. (*Mullard Tech. Commun.*, vol. 3, pp. 254–256; January, 1958.) The performance of the amplifier is discussed when used with magnetic and crystal pickups, tape recorder play-back heads, and microphone and radio inputs.

621.375.2.029.63 2024

Straight P.A. for 70 Centimetres—J. A. Plowman. (*Short Wave Mag.*, vol. 15, pp. 595–597; January, 1958.) Design and operating details for a RF amplifier on 430 mc using a double tetrode.

621.375.23.029.3 2025

A Nonlinear Low-Frequency Instability Phenomenon in Audio Amplifiers—T. Usher, Jr. (*Commun. & Electronics*, no. 34, pp. 698–701; January, 1958.) Under certain conditions, AF amplifiers with feedback may show instability at low frequencies, which is not predictable by conventional linear analysis. The problem is analyzed theoretically with supporting experimental results and a technique given for reducing the nonlinear effect.

621.375.232.3 2026

Some Augmented Cathode-Follower Circuits—J. R. Macdonald. (IRE Trans. on Audio, vol. AU-5, pp. 63–70; May/June, 1957.) Direct-coupled cathode-follower circuits with very high input and low output impedance are described, suitable for driver stages (see, *e.g.*, 2888 of 1955), buffer stages and frequency-selective amplifiers.

621.375.3 2027

Magnetic Amplifiers: Basic Principles and Applications—L. W. Stammerjohn. (*Bell Lab. Record*, vol. 36, pp. 16–20; January, 1958.) A basic qualitative description of the principles of operation.

621.375.4:621.317.3 2028

1-kc/s Transistor High-Gain Tuned Amplifier—R. A. Hall. (*Electronic Eng.*, vol. 30, pp. 192–195; April, 1958.) "Particular attention has been paid to stability of gain and bandwidth against transistor variations; over a period of 12 months the maximum gain of about 125 db has changed by only 1.5 db with no measurable change in bandwidth. The amplifier has been designed principally for use as a bridge detector and general-purpose amplifier, but provision has also been made for transistor noise-figure measurements by the addition of a stage at the input in which the transistor under test provides sufficient gain to make the effective noise figure of the amplifier negligible for most purposes."

621.375.4.029.3 2029

A Stable-Gain Transformer-Coupled Transistor A.F. Amplifier—H. Kemhadjian. (*Mullard Tech. Commun.*, vol. 3, pp. 245–251; January, 1958.) The amplifier is designed primarily for use with dc choppers giving a square-wave output at 400 cps. Circuit diagrams are given and the performance is illustrated by graphs. Changes in the transformer design for use at other frequencies are discussed.

621.375.4.029.3:621.314.7 2030

A Transistorized Decade Amplifier for Low-Level Audio-Frequency Applications—A. B. Bereskin. (IRE Trans. on Audio, vol. AU-5, pp. 138–142; September/October, 1957. Abstract, Proc. IRE, vol. 46, pp. 800–801; April, 1958.) 1957 National Electronics Conference paper.

621.375.4.072 2031

A Generalized Theory of Transistor Bias Circuits—H. Hellerman. (*Commun. & Electronics*, no. 34, pp. 694–697; January, 1958.) A general method of analyzing bias circuits is presented. Almost all three-terminal bias circuits can be reduced to the same standard form for which the analysis is given. An example from current practice shows the unifying concepts resulting from the general theory.

621.375.4.123 2032

Transistor Amplifier Stages Operating from 6, 9 and 12 V—O. J. Edwards. (*Mullard Tech. Commun.*, vol. 3, pp. 251–253; January, 1958.) A description of low-level stages using a Type-OC71 transistor which can be used to build RC-coupled amplifiers operating in ambient temperatures up to 45°C.

621.375.422.029.3 2033

Direct-Coupled Transistor Audio Amplifier—D. A. G. Tait. (*Wireless World*, vol. 64, pp. 237–239; May, 1958.) Description of a design procedure for a three-stage amplifier in which the collector of one stage is directly connected to the base of the following stage. See 627 of 1958 (Milnes).

621.375.9:538.569.4:538.221 2034

Parametric Amplification using Low-Frequency Pumping—S. Bloom and K. K. N. Chang. (*J. Appl. Phys.*, vol. 29, p. 594; March, 1958.) Describes how low-frequency pumping is possible if two pumping sources are used in conjunction with a nonlinear reactance having an odd-order nonlinearity. An analysis of the equivalent circuit is given.

621.375.9:538.569.4:538.221 2035

A Traveling-Wave Ferromagnetic Amplifier—P. K. Tien and H. Suhl. (Proc. IRE, vol. 46, pp. 700–706; April, 1958.) Amplification of signal power can be obtained in a propagating structure which is partially or totally embedded in a ferromagnetic medium. It is shown that one form of the structure possesses two propagating modes and can also support a traveling wave supplied by a local oscillator which provides through the magnetic changes a time-varying coupling between the two propagating modes. The principle of operation is illustrated by a simple transmission-line model.

621.375.9:538.569.4.029.64 2036

Contribution to the Theory of the Molecular Generator—Yu. L. Klimontovich and R. V. Khokhlov. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1150–1155; May, 1957.) The resonance interaction between an electromagnetic field and a molecular beam, and self-oscillatory processes in a molecular oscillator are investigated for the case of a single-velocity beam. Results obtained taking account of "nonmonochromatic" molecules in the beam are considered qualitatively.

621.375.9:538.569.4.029.64 2037

Operation of a Three-Level Solid-State Maser at 21 cm—J. O. Artman, N. Bloembergen, and S. Shapiro. (*Phys. Rev.*, vol. 109, pp. 1392–1393; February 15, 1958.) A three-level paramagnetic solid-state maser has been operated both as an amplifier and as an oscillator at 1373 mc. A single crystal of about 1 cm³ of $K_3Co(CN)_6$ containing 0.5 per cent $K_3Cr(CN)_6$ as active element is used.

621.375.9:621.385.029.64:537.533 2038

Parametric Amplification of Space-Charge Waves—Louisell and Quate. (See 2273.)

621.376.2:621.318.134 2039

The Magnetic Ring Modulator and Demodulator—R. Elsner and L. Pungs. (*Nachrtech. Z.*, vol. 10, pp. 436–438; September, 1957.) Advantages and disadvantages are outlined with reference to the equivalent circuit and to a practical modulator for use with a 10-kc carrier frequency.

621.376.32 2040

Multiplication of Frequency-Modulated Oscillations over an Extremely Wide Frequency Range—H. Schönfelder. (*Frequenz.*, vol. 11, pp. 274–278; September, 1957.) The problem of multiplying in a ratio 1:1000 with a fundamental frequency of 100 kc is discussed with reference to the performance of a serrasoid modulator (279 of 1954). See also 1378 of 1958.

621.376.32:621.318.134 2041

Frequency Modulation by Inductance Variation: a Magnetically Stable Ferrite Modulator—F. Slater. (*J. Brit. IRE*, vol. 18, pp. 189–204; March, 1958.) The operation of modulators incorporating a reactance tube or a variable inductance is summarized. The losses in the magnetic core of the inductance modulator are considerably reduced by using magnetic ferrites, and details of this type of modulator are given. It can be used in simple variable-frequency circuits up to 500 mc.

621.376.32:621.318.134 2042

Simple Circuit Stabilizes Ferrite F.M. Modulator—A. B. Przedpelski. (*Electronic Ind.*, vol. 17, pp. 56–57; February, 1958.) Stabilization over a range of frequencies is achieved by the use of an auxiliary fixed-frequency oscillator and associated feedback control circuit.

621.374.32:621.387.4 2043

Multichannel Pulse Height Analysers [Book Review]—H. W. Koch and R. W. Johnston, eds. Publishers: National Academy of Sciences—National Research Council, Washington, D. C., 1957, 205 pp. (*Nature, London*, vol. 180, p. 1381; December 21, 1957.) Proceedings of an informal conference held at Gatlinburg, Tennessee, September 26–28, 1956.

621.375.4.029.3 2044

Transistor A.F. Amplifiers [Book Review]—D. D. Jones and R. A. Hilbourne. Publishers: Iliffe & Sons, London, 1957, 152 pp. (*J. Electronics Control*, vol. 4, p. 96; January, 1958.)

GENERAL PHYSICS

530.12 2045

A Variational Principle for Classical Field Theories—J. Pachner. (*Ann. Physik.*, vol. 19, pp. 353–368; May 10, 1957.)

530.12:537.21 2046

The Definition of Current Charge and Electric Force in the Unified Field Theory—H. Treder. (*Ann. Physik.*, vol. 19, pp. 369–380; May 10, 1957.)

535.13 2047

On the Deduction of the Lorentz-Einstein Transformation from Maxwell's Electromagnetic Field Equations—K. Stiegler. (*Proc. Phys. Soc., London*, vol. 71, pp. 512–513; March 1, 1958.)

535.223:538.566.029.65 2048

Precision Determination of the Velocity of Electromagnetic Waves—K. D. Froome. (*Nature, London*, vol. 181, p. 258; January 25, 1958.) Using an interferometer of improved performance operating at 72 kmc a value $c_0 = 299{,}792.50 \pm 0.10$ km has been obtained.

535.376:546.26-1 2049

Investigations by Microscope and Oscillograph of the Electroluminescence of Nonconducting Diamonds—E. Krautz and G. Zollfrank. (*Optik, Stuttgart*, vol. 14, pp. 446–457; October, 1957.) The electroluminescence is investigated at field strengths above 10^6 v/cm. With very strong fields and high current densities graphite whiskers form in the diamond at the electrodes and the electroluminescence is thereby enhanced. Oscillograms indicate that recombination processes are a contributory cause of electroluminescence.

537.12:538.1 2050

Magnetic Interaction of Electrons and Anomalous Diamagnetism—V. T. Geĭlikman. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1206–1211; May, 1957.)

537.311.62 2051

On the Theory of Skin Effect in Metals—M. Ya. Azbel'. (*Zh. Eksp. Teor. Fiz.*, vol. 32, p. 1259; May, 1957.) The coefficient of electromagnetic wave transmission through a sufficiently thick film is calculated taking into account a small slowly damped addition derived from the evaluation of the spin magnetic moment.

537.312.62 2052

Critical Current for Superconducting Films—V. L. Ginzburg. (*Doklady Akad. Nauk S.S.S.R.* vol. 118, pp. 464–467; January 21, 1958.) Mathematical analysis of critical currents for superconducting films 10^{-5}–10^{-6} cm thick.

537.525.6 2053

Emission Mechanism of Cold-Cathode Arcs—K. G. Hernqvist. (*Phys. Rev.*, vol. 109, pp. 636–646; February 1, 1958.) A new theory is proposed in which excited atoms play a predominant role as a source for ion generation in the vicinity of the cathode surface. The processes of resonance ionization and of ionization in the strong electric field at the cathode surface are considered.

537.533:621.385.032.269.1 2054

A General Theorem for Dense Electron Beams—A. R. Lucas, B. Meltzer, and G. A. Stuart. (*J. Electronics Control*, vol. 4, pp. 160–164; February, 1958.) A sufficient condition for the existence of any particular set of trajectories is derived for Pierce-type dense electron beams.

537.533.79:537.226.3:538.561 2055

Energy Loss by a Charged Particle Passing through a Laminar Dielectric: Part 1—Ya. B. Fainberg and N. A. Khizhryak. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 883–895; April, 1957.) A general expression has been obtained for losses of a particle moving in an unbounded laminar medium or a waveguide filled with a dielectric. Polarization losses are examined and an expression for the spectral distribution of parametric Cherenkov radiation is derived.

537.56 2056

Electron-Electron Interaction and Heat Conduction in Gaseous Plasmas—L. Goldstein and T. Sekiguchi. (*Phys. Rev.*, vol. 109, pp. 625–630; February 1, 1958.) The thermal conductivity in low-gas-pressure Ne and Xe plasmas has been shown experimentally to be determined chiefly by heat flow in the electron gas of the plasma. The experimentally determined values of the thermal conductivity are in agreement, within less than one order of magnitude, with those given by the theory of Spitzer and Härm (*ibid.*, vol. 89, pp. 977–981; March 1, 1953.)

537.56 2057

Energy Exchange Between Electron and Ion Gases through Coulomb Collisions in Plasmas—A. A. Dougal and L. Goldstein. (*Phys. Rev.*, vol. 109, pp. 615–624; February 1, 1958.) The general aspects of energy exchange between the electron, ion, and molecular constituent gases and their energy transfer to the boundary have been examined experimentally for a partially ionized gas. Coulomb collisions between electrons and ions are shown to contribute significantly to thermal energy transfer from the electron gas, even in weakly ionized gases. In a plasma produced in Ne gas at 2.25 mm Hg at 300°K, the characteristic time for equipartition of excess mean electron energy with the ion gas varies from 11 to 5μs as the ion concentration increases from 1.6 to 5.8×10^{11} cm^{-3}.

537.56 2058

Theory of Electric Waves in Inhomogeneous Plasmas—K. Kischel. (*Ann. Physik.*, vol. 19, pp. 309–321; May 10, 1957.) Dispersion functions are derived for longitudinal waves in plasmas of variable electron density. The special case of a quasi-neutral electron beam of spatially variable density is discussed.

537.56 2059

Simplification of Equations for the Distribution Function of Electrons in a Plasma—A. V. Gurevich. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1237–1238; May, 1957.) An analysis based on the Boltzmann kinetic equation, considering initially a spatially homogeneous plasma located in electric and magnetic fields.

537.56 2060

Contribution to the Theory of Transport Processes in a Plasma Located in a Magnetic Field—E. S. Fradkin. (*Zh. Eskp. Teor. Fiz.*, vol. 32, pp. 1176–1187; May, 1957.) The mean statistical characteristics such as velocity, heat flow, and stress tensor are determined.

537.56 2061

Space-Charge, Field Emission and the Ionic Condenser—H. Ritow. (*J. Electronics Control*, vol. 4, pp. 97–110; February, 1958.) High electrostatic fields measured at the electrodes during gas discharge experiments in H indicate that the mechanism initiating a flash of intermittent glow is field emission from the cathode or from the negative space charge. The hypothesis is applied to the experimental results of other workers and is confirmed. It is shown to provide simple explanations for many gas discharge phenomena. It is suggested that the measured high fields are due to concentrated space charges forming ionic condensers with the electrodes or within the gas itself in the form of stationary striations.

537.56:535.33 2062

Statistical Broadening of Spectral Lines Emitted by Ions in a Plasma—M. Lewis and H. Margenau. (*Phys. Rev.*, vol. 109, pp. 842–845; February 1, 1958.)

537.56:538.566 2063

Ponderomotive Force in Localized Plasma in the Electromagnetic Field of a Plane Wave—V. V. Yankov. (*Zh. Eksp. Teor. Fig.*, vol. 32, pp. 926–927; April, 1957.) A sphere of uniormly ionized gas is considered as a rough odel of localized plasma. The radius of this phere is smaller than the wavelength of the eld in vacuum or in plasma. Expressions for e internal and surface intensities of the poneromotive force are derived.

37.56:538.566 2064

Excitation of Plasma Oscillations and rowing Plasma Waves—G. D. Boyd, L. M. ield, and R. W. Gould. (*Phys. Rev.*, vol. 109, p. 1393–1394; February 15, 1958.) Report of reliminary results of a new experiment in hich the beam is modulated by a microwave gnal before it interacts with the plasma. A ery strong interaction is observed which hows essentially the theoretically predicted orm of behavior.

37.56:538.63 2065

Movements of Rarefied Plasma in an Alernating Magnetic Field—Ya. P. Terletskiĭ. *Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 927–928; pril, 1957.) An expression is derived showing hat even with constant current the energy of otation of plasma particles can increase many imes in consequence of the decrease of the adius.

38.114 2066

Contribution to the Theory of Anisotropy f Ferromagnetic Single Crystals—N. A. otapkov. (*Doklady Akad. Nauk S.S.S.R.*, ol. 118, pp. 269–272; January 11, 1958.) A athematical analysis based on Dyson's heory of spin-wave interaction (3696 of 1956) applied to the investigation of anisotropic erromagnets of hexagonal symmetry.

38.22:538.569.4 2067

Paramagnetic Resonance and Polarization f Nuclei in Metals—M. Ya. Azbel', V. I. eraskimenko, and I. M. Lifshits. (*Zh. Eksp. eor. Fiz.*, vol. 32, pp. 1212–1225; May, 1957.) theory of paramagnetic resonance is proosed based on simultaneous solutions of Maxell's equations and the kinetic equation for e density operator. It is shown that the olarization varies with depth and also that e paramagnetic resonance gives rise to selecve transparency in metallic films.

38.249 2068

Basic Features of Néel's Theory of Impurity tom After-Effects—F. Schreiber. (*Z. angew. hys.*, vol. 9, pp. 203–212; April, 1957.) xposition in simple terms of Néel's theory of agnetic diffusion after-effects (3072 of 1952). he equivalent circuit of a Bloch wall is deved which allows for the influence of impurity toms. Thirty-three references.

83:550.38 2069

Two-Dimensional Problems of the Decay f Magnetic Fields in Magnetohydrodynamics— . G. Cowling and A. Hare. (*Quart. J. Mech. ppl. Math.*, vol. 10, pt. 4, pp. 385–405; Novemer, 1957.) The normal modes of decay of agnetic fields in conducting fluids are studied r different classes of steady motion. See 1328 f 1955 (Bullard and Gellman).

38.56.029.64:531.61 2070

On a Macroscopic Measurement of the pin of Electromagnetic Radiation—G. Torldo di Francia. (*Nuovo Cimento*, vol. 6, pp. 50–167; July 1, 1957.) (In English.) The spin f electromagnetic radiation may be deduced om the torque exerted at microwave freuencies by a circularly polarized wave upon a reen which can conduct current only parallel a given direction [see 354 of 1950 (Carara)]. Calculations are made of the angularomentum and scattering cross-sections of the reen, and the feasibility of an accurate experiment is discussed.

538.561:537.122 2071

The Cherenkov Effect in Composite (Isotropic) Media—A. M. Sayied. (*Proc. Phys. Soc., London*, vol. 71, pp. 398–404; March 1, 1958.) A theoretical investigation based on the invariance of Maxwell's equations. The case of two coaxial dielectrics and permeable cylinders with a common cylindrical interface, and a charged particle moving along their common axis is considered. Results are discussed with particular reference to Cherenkov radiation at radio and microwave frequencies. The effect of coherence on the output of the emitted radiation is outlined.

538.561:537.533 2072

Radiation from a Point Charge Moving Uniformly along the Surface of an Isotropic Medium—A. I. Morozov. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1260–1261; May, 1957.) Energy emitted per unit of time by a particle moving along a surface in a nondispersive medium is calculated. Expressions are derived for relativistic and nonrelativistic conditions and for magnetic and ferrite-type media. See also 1628 of 1955 (Danos).

538.566:535.42 2073

Diffraction by Cylindrical Reflectors—R. Plonsey. (*Proc. IEE*, pt. C, vol. 105, pp. 312–318; March, 1958.) Measurements of the near-zone diffracted field of a cylindrical reflector with a line source at the center agree with calculations using geometrical-optics current. The equivalent line currents give slightly better agreement.

538.566:537.562 2074

The Propagation of Slow Electromagnetic Waves along Inhomogeneous Plasma Layers—W. Oehrl. (*Z. angew. Phys.*, vol. 9, pp. 164–171; April, 1957.) On the basis of Schumann's work (see, *e.g.*, 712 of 1953) the special case of surface waves in the plasma and the adjoining layers of air is considered.

538.569.4 2075

Molecular-Beam Resonances in Oscillatory Fields of Nonuniform Amplitudes and Phases—N. F. Ramsey. (*Phys. Rev.*, vol. 109, pp. 822–825; February 1, 1958.) The transition probability equations are reduced to forms which are suitable for digital computer calculations. A computer program for the calculation of the shapes of the resonances is described.

538.63 2076

Quantum Theory of Galvanomagnetic Effects—P. N. Argyres. (*Phys. Rev.*, vol. 109, pp. 1115–1128; February 15, 1958.) A study is made of the effect of the quantization of the electron orbits in a magnetic field on the galvanomagnetic properties of an isotropic semiconductor or semimetal in the phonon-scattering range. The conductivity tensor is calculated using the quantum-mechanical density operator. The Hall coefficient and transverse resistivity are studied for a number of different sets of conditions for electron density, magnetic field, and temperature.

539.2 2077

Theoretical Investigation of the Electronic Energy Band Structure of Solids—F. Herman. (*Rev. Mod. Phys.*, vol. 30, pp. 102–121; January, 1958.) A review including sections dealing with a) the elements of energy-band theory, b) the uses of group theory and perturbation theory c) a survey of numerical methods for solving the crystal wave equation, d) examples illustrating complex energy-band structures. A representative list of about 200 references is given. Experimental techniques are discussed by Lax (2078 below).

539.2 2078

Experimental Investigations of the Electronic Band Structure of Solids—B. Lax. (*Rev. Mod. Phys.*, vol. 30, pp. 122–154; January, 1958.) Experiments are discussed which have been of value in contributing to current knowledge of the band structure of many materials of importance at present. The experiments mentioned include those involving the de Haas-van Alphen effect, cyclotron resonance, the galvanomagnetic effect, and infrared absorption. One hundred and seventy-two references.

539.2 2079

Electron Interaction in Solids. General Formulation—P. Nozières and D. Pines. (*Phys. Rev.*, vol. 109, pp. 741–761; February 1, 1958.) A general Hamiltonian formalism is developed to treat from first principles the motion of electrons in solids, including their mutual Coulomb interaction. It is shown that, under suitable circumstances, plasmons (the quanta of the plasma oscillations) represent a well-defined elementary excitation of the solid. The "existence criterion" for plasmons is found to be a high electronic polarizability. After the plasmon modes are separated out, the remaining electron interaction is found to be screened, with a range of the order of the interelectron spacing. The usefulness of this effective Hamiltonian for the calculation of the electronic energy levels and cohesive energy in solids is discussed briefly.

539.2 2080

Electron Interaction in Solids. Collective Approach to the Dielectric Constant—P. Nozières and D. Pines. (*Phys. Rev.*, vol. 109, pp. 762–777; February 1, 1958.) A quantum theory of the dielectric constant for solids of both low and high polarizability is developed from first principles. In the latter case, the approach used is collective in that the long-range part of the electron interaction is described by the plasmon field. Both the static and frequency-dependent dielectric constant are derived. It is shown that the interaction between electrons may be described in terms of the dielectric constant of the solid provided the electrons in question form a small minority group which can be isolated from the much larger majority electron group.

539.2 2081

Electron Interaction in Solids. The Nature of Elementary Excitations—P. Nozières and D. Pines. (*Phys. Rev.*, vol. 109, pp. 1062–1074; February 15, 1958.) Possible elementary excitations in solids are studied with the aid of the general theoretical approach developed in the preceding papers of this series (2079 and 2080 above). Particular attention is paid to the basic theoretical justification for the individual-particle-like elementary excitation ("effective" electrons). It is concluded that good qualitative arguments could now be given for the existence of effective electrons in solids. The presence of an energy gap is shown to be a necessary condition for the existence of strong spatial correlations between minority carriers in solids; and the nature of such correlated minority electron excitations is discussed.

539.2:538.221:621.318.134 2082

Approximate Theory of Ferrimagnetic Spin Waves—T. A. Kaplan. (*Phys. Rev.*, vol. 109, pp. 782–787; February 1, 1958.) "The wave functions and the energy spectrum for the spin-wave problem in a normal spinel are found by means of a straightforward extension of Anderson's approach to antiferromagnetism (*ibid.*, vol. 86, pp. 694–701; June 1, 1952). Only A-B exchange is assumed to exist, and the calculation is carried to second order in the magnitude of the propagation vector, $\boldsymbol{k}$. Five distinct energy surfaces (E *vs* k) are found, two of which are identical, in the classical limit, to the ones previously reported by H. Kaplan (*ibid.*, vol. 86, p. 121; April 1, 1952.)."

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.164.3:621.396.11 2083
Propagation of Radio Waves from Cosmical Sources—E. Chvojková. (*Nature, London*, vol. 181, p. 105; January 11, 1958.) A formula is given for the refraction of radio waves reaching the earth's atmosphere from outside. The formula may be applied to waves from artificial earth satellites.

523.164.32:523.75 2084
A New Spectral Characteristic in Solar Radio Emission—A. Maxwell and G. Swarup. (*Nature, London*, vol. 181, pp. 36–38; January 4, 1958.) Equipment at Fort Davis, Texas, covers the band 100–580 mc and comprises a 28-foot-diameter parabolic antenna with three broad-band primary arrays coaxially mounted at its focus [see 1126(l) of 1958 (Maxwell, *et al.*)]. A new type of fast burst having a frequency/time graph in the form of an inverted U and of duration 3–10 seconds is reported, and the possible origin of these bursts is discussed.

550.38:523.165 2085
Effective Magnetic Meridian for Cosmic Rays—J. R. Storey, A. G. Fenton, and K. G. McCracken. (*Nature, London*, vol. 181, p. 34; January 4, 1958.) Observations of the cosmic-ray meridian made with neutron intensity monitors at Melbourne, Australia, are reported. Doubts are expressed about the equivalent-dipole theory of the earth's magnetic field [see, *e.g.*, 3721 of 1956 (Simpson *et al.*)].

550.389.2:629.19 2086
Scientific Observations of the Artificial Earth Satellites and their Analysis—H. S. W. Massey and R. L. F. Boyd. (*Nature, London*, vol. 181, pp. 78–80; January 11, 1958.) Report of a discussion held by the Royal Society on November 29, 1957.

550.389.2:629.19 2087
Lifetime of an Artificial Russian Satellite—J. A. Fejer. (*Nature, London*, vol. 180, p. 1413; December 21, 1957. A simple formula for the calculation of lifetime from data on the initial orbit is given. It was applied to observations made at Johannesburg of the Doppler effect on signals received at 40.002 mc from the first Russian satellite.

550.389.2:629.19 2088
Interception of Radio Signals Transmitted by the Satellite 'Sputnik I'—P. F. Checcacci, V. Russo, and C. Carreri. (*Ricerca sci.*, vol. 27, pp. 3252–3260; November, 1957.) Brief outline of apparatus and methods used; some recordings of the 20 and 40-mc transmissions obtained in Florence are reproduced.

550.389.2:629.19 2089
Observations in Australia of Radio Transmissions from the First Artificial Earth Satellite—G. H. Munro and R. B. White. (*Nature, London*, vol. 181, p. 104; January 11, 1958.) Observations of the strength of 20 and 40-mc signals were made at Bringelly, near Sydney, Australia. The rate of fading appears to be a minimum when the direction of propagation of the wave is nearly perpendicular to the earth's magnetic field.

551.510.535 2090
Ionospheric Drift in the F_2 Region near the Magnetic Equator—B. W. Purslow. (*Nature, London*, vol. 181, pp. 35–36; January 4, 1958.) Graphs of the diurnal variations of drift in the F_2 layer based on observations made at Singapore from September, 1953 to August, 1956 suggest that the drift is predominantly in an E-W direction and has a maximum value of about 90 meters per second.

551.594.5:621.396.11:551.510.535 2091
Artificial Aurora—(*Electronic and Radio Engr.*, vol. 35, pp. 168–170; May, 1958.) The Luxembourg effect is explained, and the possibility of using it to produce a luminous dischage in the E layer is discussed.

551.594.5:621.396.96 2092
Determination of Auroral Height by Radar—R. S. Unwin and M. Gadsden. (*Nature, London*, vol. 180, pp. 1469–1470; December 28, 1957.) Preliminary report of observations made during the I.G.Y. at a radar station erected at 885 feet above sea level at Bluff in the South Island of New Zealand. Echoes have been recorded at 55 mc from heights of about 110 km and ranges up to about 1250 km to the south.

551.594.6:621.317.3 2093
Atmospheric Radio Noise—Harwood and Nicolson. (See 2176.)

LOCATION AND AIDS TO NAVIGATION

621.396.663 2094
Cable Symmetry Requirements for Two-Channel Direction Finders—G. Ziehm. (*Frequenz*, vol. 11, pp. 287–294; September, 1957.) The effects of differences in length of the cables connecting d.f. antenna systems to the receiver are investigated. Tolerances for these differences and for matching antennas to the receiver input are evaluated.

621.396.93+621.396.96] .061.3 2095
Radio Navigational Aids—(*Wireless World*, vol. 64, pp. 210–211; May, 1958.) Digest of papers presented at an IEE Convention held in London, March 27–28, 1958.

621.396.933.2:621.396.677.6 2096
Study of the Feasibility of Airborne H.F. Direction-Finding Antenna Systems—P. S. Carter, Jr. (IRE Trans. on Aeronautical and Navigational Electronics, vol. ANE-4, pp. 19–23; March, 1957. Abstract, Proc. IRE, vol. 45, p. 1034; July, 1957.)

621.396.96:621.372.5 2097
Synthesis of Delay-Line Networks—Linden and Steinberg. (See 2006.)

621.396.96:621.396.665 2098
The Design of Automatic-Gain-Control Systems for Auto-tracking Radar Receivers—J. C. G. Field. (*Proc. IEE*, pt C, vol. 105, pp. 93–108; March, 1958.) The AGC requirements for conical-scanning-type radars and practical methods of control are reviewed. Design methods are illustrated by a description of the development of a system for a particular fire-control radar and the results of operational trials are briefly described.

621.396.969:629.13 2099
Effect of Precipitation on the Design of Radio Altimeters—R. K. Moore. (IRE Trans. on Aeronautical and Navigational Electronics, vol. ANE-4, pp. 24–29; March, 1957. Abstract, Proc. IRE, vol. 45, p. 1034; July, 1957.) See also 1457 of 1957 (Moore and Williams).

621.396.969.3 2100
Atmospheric Angels Mimic Radar Echoes—V. G. Plank. (*Electronics*, vol. 31, pp. 140–144; March 14, 1958.) The false echoes due to atmospheric conditions, insects, or birds are discussed. Echoes due to layers, clouds, wind-carried and other sources are considered, together with meteorological data. Unexplained traces which move rapidly across the screen and then disappear are also mentioned.

621.396.969.34:621.396.933.2 2101
The Air Traffic Control Radar Beacon System—D. S. Crippen. (IRE Trans. on Aeronautical and Navigational Ele tronics, vol. ANE-4, pp. 6–15; March, 195 Abstract, Proc. IRE, vol. 45, p. 1034; Jul 1957.)

MATERIALS AND SUBSIDIARY TECHNIQUES

535.215:546.561 210
Photoconductivity of Cuprite—A. N. Krongauz, V. K. Lyapidevskiĭ, and Yu. S. Deev (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1012–101 May, 1957.) Investigations of the temperatur dependence of photoconductivity indicate th occurrence of peaks for both positive and negative photoconductivity [see 2448 of 195 (Krongauz and Lyapidevski)]. The combine effects of X rays and visible light depend o the sequence of the illumination processes.

535.215:546.817.221:539.23 210
Quantum Efficiency of Photoconductiv Lead Sulphide Films—H. E. Spencer. (*Phys Rev.*, vol. 109, pp. 1074–1075; February 15 1958.) By using photoconductivity measurements it is shown that the quantum efficienc of lead sulphide films is almost unity. Mobilities calculated from photoconductivity dat agree with mobilities obtained from noise an Hall measurements. It is concluded that nois at room temperature is not photon noise.

535.215:546.863.221 210
Structural Characteristics of Antimon Sulphide Layers—V. N. Vertsner, B. V. Gorbunov, and Ya. A. Oksman. (*Zh. Eksp. Teor Fiz.*, vol. 32, pp. 957–961; May, 1957.) A electron-diffraction investigation shows tha when a layer condenses on a heated backing i consists of an amorphous mass of Sb_2S_3 and thin surface film of Sb_2O_3. The photosensitivit appears to be determined by the crystallin oxide which acts as an additional trappin center for the current carriers.

535.37:[546.472.21+546.482.21]:535.215 210
De-excitation of ZnS and ZnCdS Phosphores by Electric Fields—H. Kallmann, B Kramer, and P. Mark. (*Phys. Rev.*, vol. 10 pp. 721–729; February 1, 1958.) The chang of photoconductivity of power samples brough about by external ac and dc fields, applie both during and after excitation with ultra violet light, is described and compared wit impedance changes due to irradiation wit infrared light. The de-excitation and recover phenomena observed are explained by a consideration of the distribution of conductio electrons created by the application of th field.

535.37:548.52 210
The Synthesis of Single Crystals of th Sulphites of Zinc, Cadmium and Mercury an of Mercuric Selenide by Vapour-Phas Methods—D. R. Hamilton. (*Brit. J. App Phys.*, vol. 9, pp. 103–105; March, 1958.) Conditions of growth are examined in the light o recent theory.

535.376 210
Electroluminescence of Zinc Sulphoselenide Phosphors with Copper Activator an Halide Coactivators—I. J. Hegyi, S. Larach and R. E. Schrader. (*J. Electrochem. Soc.*, vo 104, pp. 717–721; December, 1957.)

535.376 210
Electroluminescence and Field Effects i Phosphors—H. F. Ivey. (*J. Electrochem. Soc* vol. 104, pp. 740–748; December, 1957.) review of the effects of applied electric fields o phosphors with or without other means o excitation. Possible explanations are given i terms of solid-state and semiconductor theorie Eighty-one references.

535.376:546.681.18 210
Grain Boundaries and Electroluminescenc

in Gallium Phosphide—D. A. Holt, G. F. Alfrey, and C. S. Wiggins. (*Nature, London*, vol. 181, p. 109; January 11, 1958.) Light sources form a pattern of narrow lines and are identifiable with grain boundaries. See also 1433 of 1956 (Wolff *et al.*).

535.376:621.386.1 **2110**
Investigation of an X-Ray Tube with Control Grids. Application to the Study of Phosphorescence—A. Pfahnl. (*Rev. Gén. Élect.*, vol. 66, pp. 159–186; March, 1957.) A comparison of the results of phosphor excitation by X rays and by electron beams is included.

537.226:538.566.2.029.63 **2111**
Metal-Flake Artificial Dielectric—S. Swarup. (*Electronic and Radio Engr.*, vol. 35, pp. 179–182; May, 1958.) The validity of various expressions for the dielectric constant of obstacle-type dielectrics has been checked experimentally at 14.7 cm λ. A new expression for the metal-flake artificial dielectric compares well with experimental results. Some anomalous results are attributed to ferrous impurities in the aluminum powder used.

537.226:546.431.824 **2112**
Dielectric Properties of Single-Domain Crystals of $BaTiO_3$ at Microwave Frequencies—T. S. Benedict and J. L. Durand. (*Phys. Rev.*, vol. 109, pp. 1091–1093; February 15, 1958.) Describes the measurement of the small-signal dielectric constant at 24 kmc from 25°C to 170°C and the measurement of the effect of a dc field on the dielectric constant at that frequency.

537.226/.227:546.431.824-31 **2113**
The Effect of Small Additions of Magnesia on some High-Permittivity Ceramics Based on Barium Titanate—K. W. Plessner and R. West. (*J. Electronics Control*, vol. 4, pp. 51–57; January, 1958.) "The presence of magnesia in barium titanate and its solid solutions (*e.g.*, with calcium zirconate or calcium stannate) greatly improves the sintering of the ceramic, the pore space being reduced to about 1 per cent in some cases. At the same time the permittivity maximum is flattened and displaced to lower temperatures by about 70°C and 0.5 per cent magnesia. It is shown that the magnesium probably enters the lattice at both barium and titanium sites."

537.227:547.476.3 **2114**
Plotting the Thermodynamic Potential of Rochelle Salt from Results of an Optical Investigation of Domains—V. L. Indenbom and M. A. Chernysheva. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 697–701; April, 1957.)

537.227:547.476.3:534.213-8 **2115**
Sound Absorption with Phase Transformation in Rochelle Salt—I. A. Yakovlev, T. S. Velichkina, and K. N. Baranskiĭ. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 935–936; April, 1957.) An investigation of plates of Rochelle salt using 1–5 μsec-pulses at 5 mc. The variation of absorption with temperature is shown graphically.

537.228.1:548.0].001.4(083.7) **2116**
I.R.E. Standards on Piezoelectric Crystals: Determination of the Elastic, Piezoelectric, and Dielectric Constants—the Electromechanical Coupling Factor, 1958—(Proc. IRE, vol. 46, pp. 764–778; April, 1958.) Standard 58 IRE 14.S1.

537.311.33 **2117**
The Theory of Electrical Conductivity of Semiconductors at High Frequencies: Part 1—H. Stolz. (*Ann. Physik*, vol. 19, pp. 394–400; May 10, 1957.) Boltzmann's equation is solved for a harmonic time-dependent electric field, allowing for the depolarization effects encountered in measurements of conductivity by means of cavity resonators. Results obtained for *n*-type Ge at cm λ are discussed.

537.311.33 **2118**
Recombination of Excess Carriers in Semiconductors—J. Okada. (*J. Phys. Soc. Japan*, vol. 12, pp. 1338–1344; December, 1957.) A multiple-level model for recombination is discussed. The results with *n*-type Ge samples are explained in terms of a recombination level at 0.30 ev below the conduction band and a hole trapping level at 0.30 ev above the valence band. For samples with a high dislocation density, the minority-carrier lifetime is found to vary with the dislocation density.

537.311.33 **2119**
Theory of the Enriched Barrier Layer on the Surface of Semiconductors—G. Heiland. (*Z. Physik*, vol. 148, pp. 28–33; March 4, 1957.) The model for which the differential equation is solved consists of a surface layer of donors on an *n*-type semiconductor, such as is formed by absorption or reaction (see, *e.g.*, 2140 below). Both low and high electron densities are considered.

537.311.33 **2120**
A Possible Mechanism for the Increase of Conductivity of Atomic Semiconductors in a Strong Electric Field—F. G. Bass. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 863–865; April, 1957.) The effect on conductivity of the slowing down of electron recombination by a strong electric field is examined.

537.311.33 **2121**
Remarks on the Theory of the Electron Plasma in Semiconductors—V. L. Bonch-Bruevich. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1092–1097; May, 1957.) The scattering of current carriers by charged impurities is examined in the light of the many-electron theory of semiconductors. At low temperatures plasma screening has a considerable effect on scattering. The ionization energy of impurity centers depends on their concentration, and decreases when the latter increases.

537.311.33 **2122**
Special Problems of Depletion—Layer Semiconductors—M. Falter. (*Nachrtech Z.*, vol. 7, pp. 405–411; September, 1957.) Survey of theory dealing with the influence of lattice defects and surface recombination on semiconductor characteristics.

537.311.33 **2123**
Transient Recombination of Excess Carriers in Semiconductors—G. K. Wertheim. (*Phys. Rev.*, vol. 109, pp. 1086–1091; February 15, 1958.) The recombination equations for a system containing an arbitrary number of Shockley-Read recombination centers (see 420 of 1953) are formulated. Transient solutions are obtained for the decay following the injection of a pulse of carriers into a system containing one or two centers. The specific cases considered include a) the one-center case, b) the case of a recombination center with a temporary trap, and c) the case of two recombination centers.

537.311.33 **2124**
Electron-Hole Recombination Statistics in Semiconductors through Flaws with Many Charge Conditions—Chih-Tang Sah and W. Shockley. (*Phys. Rev.*, vol. 109, pp. 1103–1115; February 15, 1958.) Treatment of the nonequilibrium but steady-state statistics for holes and electrons in semiconductors with one type of multiple-charge-condition flaw. The problem is simplified by the use of a charge-distribution diagram and a recombination-ratio diagram. Through these diagrams the most important charge states of the flaws can be visualized for any injection conditions or carrier densities.

537.311.33:538.632 **2125**
The Problem of Saturation of the Hall 'Constant' in Semiconductors in Strong Magnetic Fields—F. G. Bass and M. I. Kaganov. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1233–1235; May, 1957.) An expression is derived for the Hall coefficient applicable to semiconductors with narrow energy bands.

537.311.33:546.23:537.226.2 **2126**
Dielectric Constants of Amorphous and Crystalline Selenium at 3.3-cm Wavelength—F. Eckart and H. Rabenhorst. (*Ann. Physik.*, vol. 19, pp. 381–393; May 10, 1957.)

537.311.33:[546.28+546.289 **2127**
Intrinsic Optical Absorption in Germanium-Silicon Alloys—R. Braunstein, A. R. Moore, and F. Herman. (*Phys. Rev.*, vol. 109, pp. 695–710; February 1, 1958.) The absorption spectrum has been measured as a function of temperature and composition over the entire composition range. The absorption near the threshold ($K < \mathrm{M}100$ cm^{-1}) exhibits a temperature dependence which is characteristic of phonon-assisted indirect electronic transitions. There is no temperature-independent component attributable to disorder-assisted transitions. When the phonon contribution to the absorption is explicitly taken into account, as in Macfarlane and Roberts' analysis (*e.g.*, 3646 of 1955), the experimental data yield an equivalent phonon temperature which varies from 270 ± 20°K for pure Ge to 550 ± 50°K for pure Si.

537.311.33:546.28 **2128**
Measurement of Ternary Distribution Coefficients in Silicon—D. Navon. (*J. Appl. Phys.*, vol. 29, pp. 579–582; March, 1958). "A method is described for determining the distribution coefficient of an impurity introduced into a semiconductor by a fused metal contact. Coefficients for the segregation of antimony, arsenic, gallium, and aluminium from a silver contact to silicon at 1250°C are less than at the silicon melting point (1408°C). Gold-doped contacts to silicon yield similar values for the distribution coefficient of these impurities."

537.311.33:546.28:537.312.8 **2129**
Weak-Field Magnetoresistance in *p*-Type Silicon—D. Long and J. Myers. (*Phys. Rev.*, vol. 109, pp. 1098–1102; February 15, 1958.) Measurements of the three weak-field magnetoresistance coefficients and the Hall mobility at a number of different temperatures between 77°K and 350°K have been made on *p*-type samples ranging in resistivity from 0.15 to 115Ω cm. The results indicate a marked temperature dependence of anisotropy in respect of energy band structure and/or scattering.

537.311.33:546.28:537.533 **2130**
Electron Emission from Silicon *p-n* Junctions—J. Tauc. (*Nature, London*, vol. 181, p. 38; January 4, 1958.) In addition to the emission of visible light from the breakdown region of a *p-n* junction during reverse current flow [see, *e.g.*, 3096 of 1956 (Chynoweth and McKay)], electron emission has been detected using a Geiger counter operating at 2000 volts several mm from the junction.

537.311.33:546.28:539.185.9 **2131**
Effect of Neutron Irradiation on Infrared Absorption in Silicon—W. G. Spitzer and H. Y. Fan. (*Phys. Rev.*, vol. 109, pp. 1011–1012; February 1, 1958). It was found that fast-neutron irradiation produced an absorption band at 20.5 μ. An absorption band at 3.9 μ was also observed.

537.311.33:546.28:669.046 2132
Heat Treatment of Silicon using Zone-Heating Techniques—H. C. Theuerer, J. M. Whelan, H. E. Bridgers, and E. Buehler. (*J. Electrochem. Soc.*, vol. 104, pp. 721–723; December, 1957.) Donor contamination and changes in lifetime are not necessarily introduced by heat treatment, but may be due to contaminants still left after normal etching and washing processes.

537.311.33:546.289 2133
Lifetime Measurements of Minority Carriers Across and Along a Dislocation Wall in a Germanium Crystal—R. R. Hasiguti and E. Matsuura. (*J. Phys. Soc. Japan*, vol. 12, pp. 1347–1351; December, 1957.) The spacing of dislocations in the wall was about 2×10^{-4} cm; the recombination diameter, 2.2×10^{-8} cm. The lifetime measured along the wall was 210 μs in a sample of mean lifetime 70 μs. It is suggested that the dislocation wall formed a thin *p*-type layer in an *n*-type crystal.

537.311.33:546.289 2134
Radial Variation of Minority-Carrier Lifetime in Vacuum-Grown Germanium Single Crystals—C. A. Hogarth and P. J. Hoyland. (*J. Electronics Control*, vol. 4, pp. 60–62; January, 1958.) Radial variation is found to exist with vacuum-grown crystals, but not with those grown in an inert gas; this has already been found in Si crystals.

537.311.33:546.289 2135
Lifetime of the O$^+$ Excited States in Ge^{70}—H. W. Kendall. (*Phys. Rev.*, vol. 109, pp. 861–862; February 1, 1958.)

537.311.33:546.289 2136
Lifetime Measurements of Minority Carriers in Deuteron-Irradiated Germanium Crystals—R. R. Hasiguti, E. Matsuura, and S. Ishino. *J. Phys. Soc. Japan*, vol. 12, pp. 1351–1354; December, 1957.) Very long lifetimes were measured on the deuteron-irradiated surface of *n*-type crystals which, it is suggested, is due to the formation of a thin *p*-type layer.

537.311.33:546.289:538.63 2137
Investigation of the Longitudinal and Transverse Galvanomagnetic Effect in *n*-Type Germanium Single Crystals Cut along the Main Crystallographic Axes—R. G. Annaev and A. Allanazarov. (*Doklady Akad. Nauk S.S.S.R.*, vol. 118, pp. 47–50; January 1, 1958.) Experiments carried out at 29°C on pure *n*-type Ge single crystals show how the conductivity and the galvanomagnetic effect depend on the direction of the crystallographic axes. Results for crystals cut along [100], [110] and [111] axes are shown graphically.

537.311.33:546.36.87:539.23 2138
The Optical Absorption, the Photoelectric and Thermal Emission and the Temperature Dependence of the Conductivity of Caesium-Bismuth Layers of Differing Composition—H. G. Clerc and G. Wallis. (*Ann. Physik*, vol. 19, pp. 344–352; May 10, 1957.)

537.311.33:546.41.786 2139
Trap Distributions in Calcium Tungstate Single Crystals—J. R. Cook. (*Proc. Phys. Soc., London* 1, vol. 71, pp. 422–429; March 1, 1958.) Thermoluminescence and current "glow" curves were used in the investigation. The resulting trap distribution agrees reasonably well with the results of a theoretical analysis of the photocurrent and phosphorescence decays after irradiation with ultraviolet light or gamma rays from a Co^{60} source.

537.311.33:546.47–31 2140
The Influence of Hydrogen on the Electrical Conductivity at the Surface of Zinc Oxide Crystals—G. Heiland. (*Z. Physik*, vol. 148, pp. 15–27; March 4, 1957.) The formation under the influence of hydrogen of two types of high-conductivity layer on ZnO crystals is discussed. For experimental investigation of the influence of an oxygen atmosphere, see 1105 of 1956.

537.311.33:546.472.21:548.0 2141
Electronic Energy Bands in ZnS: Potential in Zincblende and Wurtzite—J. L. Birman. (*Phys. Rev.*, vol. 109, pp. 810–817; February 1, 1958.) The nature of the chemical bond in ZnS is discussed and evidence indicating mixed covalent and ionic bonding is reviewed. Calculation shows the crystal potential to be the same for both modifications in two corresponding prominent crystallographic directions.

537.311.33:546.472.21:548.0 2142
Electronic Energy Bands in ZnS: Preliminary Results—C. Shakin and J. Birman. (*Phys. Rev.*, vol. 109, pp. 818–819; February 1, 1958.) "Preliminary results of the cellular calculations of electronic energy bands in cubic ZnS have been obtained at three points in the Brillouin zone: Γ, X, Λ. These results indicate that there is a normal order of states in the valence band, and an energy gap of 6–8 v at $\mathbf{k}=(0,0,0)$ corresponding to the $\Gamma_4'\rightarrow\Gamma_1'$ transition." See also 2141 above.

537.311.33:[546.623.86+546.682.86 2143
Influence of the Surface Area on the Type of Conductivity in AlSb and InSb—V. F. Synorov. (*Doklady Akad. Nauk S.S.S.R.*, vol. 118, pp. 483–484 January 21, 1958.) The dependence of the conductivity on grain size is investigated. For grain sizes 2–3μ the conductivity is very low and with a decrease in grain size conductivity changes from *n* type to *p* type.

537.311.33:[546.681.19+546.682.19 2144
Nuclear Magnetic Resonance in Semiconductors: Part 3—Exchange Broadening in GaAs and InAs—R. G. Shulman, B. J. Wyluda, and H. J. Hrostowski. (*Phys. Rev.*, vol. 109, pp. 808–809; February 1, 1958.) "Nuclear magnetic resonance lines have been observed for the more abundant isotopes of the semiconductors GaAs and InAs. The resonances are broader than expected from nuclear dipolar widths alone. The additional broadening is explained by the indirect nuclear exchange mechanism and is consistent with previous measurements on the homologous semiconductors InSb and GaSb." Part 1: 1107 of 1956 (Shulman *et al.*).

537.311.33:546.681.19:546.289 2145
Some Properties of Gallium Arsenide-Germanium Mixtures—D. A. Jenny and R. Braunstein. (*J. Appl. Phys.*, vol. 29, pp. 596–597; March, 1958.) The solubility of Ge in GaAs is probably less than two atomic per cent in spite of the near identity of their crystal parameters. The presence of the maximum soluble amount of Ge reduces the band gap 1.35 ev by about 0.1 ev.

537.311.33:546.682.18 2146
Some Properties of Semiconducting Indium Phosphide—W. N. Reynolds, M. T. Lilburne, and R. M. Dell. (*Proc. Phys. Soc., London*, vol. 71, pp. 416–421; March 1, 1958.) "Pure polycrystalline samples of InP have been prepared. Point-contact experiments have shown useful rectification on both *n* and *p*-type samples, as well as transistor effects with power gains up to 20 times. The infrared transmission spectrum has been extended to 20μ, and the effective mass of electrons has been estimated as 0.02*m*. Previous work on general properties has been revised and extended."

537.311.33 2147
The Indium-Selenium System—J. C. Brice, P. C. Newman, and H. C. Wright. (*Brit. J. Appl. Phys.*, vol. 9, pp. 110–111; March, 1958.) Polycrystalline specimens of In$_2$Se$_3$, InSe, and In$_2$Se were prepared by direct fusion, and their resistivity and spectral absorption characteristics were measured. The first two were found to be semiconductors, but single-phase specimens of the last were not achieved.

537.311.33:546.682.86 2148
Avalanche Multiplication and Electron Mobility in Indium Antimonide at High Electric Fields—A. C. Prior. (*J. Electronics Control*, vol. 4, pp. 165–169; February, 1958.) The *I/v* characteristic of InSb has been measured up to field strengths of 800 v/cm. Avalanche multiplication was found to occur at values above 150 v/cm. No variation of electron mobility was found.

537.311.33:546.682.86:537.312.8 2149
Magnetoresistance of *n*-Type InSb at 4.2°K—R. B. Broom. (*Proc. Phys. Soc., London*, vol. 71, pp. 470–475; March 1, 1958.) Investigations of specimens prepared by different techniques from single crystals of differing purity indicate that negative magnetoresistance is not a bulk property of the material but is largely due to the method of preparation. Oscillations in the magnetoresistance as a function of magnetic field have been observed in samples with a balanced donor concentration of less than 10^{16} cm^{-3}. Results are discussed in detail for two samples.

537.311.33:[546.812.241+546.812.231
+546.682.87 2150
Electrical Properties of SnTe, SnSe and InBi at Low Temperatures—K. Hashimoto. (*J. Phys. Soc. Japan*, vol. 12, p. 1423; December, 1957.)

537.311.33:546.873.241 2151
Galvanomagnetic Effects in *n*-Type Bismuth Telluride—J. R. Drabble, R. D. Groves, and R. Wolfe. (*Proc. Phys. Soc., London*, vol. 71, pp. 430–443; March 1, 1958.) The resistivity, Hall coefficients, and low-field magnetoresistance coefficients associated with current flow in the cleavage planes have been measured at 77°K, and over the range 100–300°K in the case of resistivity and Hall coefficients. Experimental results are reasonably consistent with a many-valley model of the band structure in which the energy minima are situated on the reflection planes. Evaluation of parameters of this model leads to relations between the two Hall coefficients and the density of carriers, which are used to obtain the conductivity mobility of electrons for current flow in the cleavage planes.

537.311.33:621.314.63:537.52 2152
Avalanche Breakdown Voltage in Hemispherical *p-n*; Junctions—J. Shields. (*J. Electronics Control*, vol. 4, pp. 58–60; January, 1958.) This voltage is calculated and a critical radius found at which a difference from a plane junction sets in; curves are given for Si *p-n* junctions. See also 3681 of 1957 (Armstrong *et al.*), and 471 of 1956 (Miller).

537.32+536.2 2153
Thermal Conductivity and Thermoelectric Phenomena in Metals in a Magnetic Field—M. Ya. Azbel', M. I. Kaganov, and I. M. Lifshits. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1188–1192; May, 1957.) Asymptotic expressions for the tensors of the thermal conductivity, and Thomson coefficients in a strong magnetic field are derived.

538.22 2154
Magnetic Properties of Oxide of Manganese at Temperatures from 20° to 300°K—A. S. Borovik-Romanov and M. P. Orlova. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 1255–1256;

May, 1957.) Graphs show the reciprocal of the magnetic susceptibility as a function of temperature for natural samples of Mn_2O_3 and Mn_3O_4.

538.22:538.569.4:549.517.13 2155

Maser Action in Ruby—G. Makhov, C. Kikuchi, J. Lambe, and R. W. Terhune. (*Phys. Rev.*, vol. 109, pp. 1399–1400; February 15, 1958.) Brief report on the results of an investigation of the electron-spin resonance properties of ruby; evidence of oscillations and amplification was obtained.

538.221+621.318.1 2156

Conference on Magnetism and Magnetic Materials—(*J. Appl. Phys.*, vol. 29, pp. 237–548; March, 1958.) The texts are given of some 120 papers presented at the conference held in Washington, D.C., November 18–21, 1957, with abstracts of others and an index of authors. Papers are grouped under 13 headings including magnetization reversal and thin films, small particles and permanent magnets, ferromagnetic resonance, magnetic moments and crystal structure of oxides, applications and testing, anisotropy and magnetostriction, magnetization processes, and magnetic apparatus and techniques. Titles of some of the papers are given below; a few others are abstracted separately.

1) **Spontaneous Magnetization of some Garnet Ferrites and the Aluminium-Substituted Garnet Ferrites**—R. Pauthenet. (pp. 253–255.)

2) **Magnetic Resonance of Ferrites with a Compensation Temperature**—J. Pauleve. (pp. 259–263.)

3) **Static and Dynamic Behaviour of Thin Permalloy Films**—D. O. Smith. (pp. 264–273.)

4) **Flux Reversal in Thin Films of 82% Ni, 18% Fe**—C. D. Olson and A. V. Pohm. (pp. 274–282.)

5) **Transverse Flux Change in Soft Ferromagnetics**—F. B. Humphrey. (pp. 284–285.)

6) **Effects of Heat Treatment of Thin Ferromagnetic Films at Intermediate Temperatures**—E. N. Mitchell. (pp. 286–287.)

7) **Reversible Rotation in Magnetic Films**—R. M. Sanders and T. D. Rossing. (pp. 288–289.)

8) **Steady-State and Pulse Measurement Techniques for Thin Magnetic Films in the V.H.F.-U.H.F. Range**—D. O. Smith and G. P. Weiss. (pp. 290–291.)

9) **Ferromagnetic Resonance and Nonlinear Effects in Yttrium Iron Garnet**—R. C. LeCraw, E. G. Spencer, and C. S. Porter. (pp. 326–327.)

10) **Substitution for Iron in Ferrimagnetic Yttrium-Iron Garnet**—M. A. Gilleo and S. Geller. (pp. 380–381.)

11) **Measurement of Losses of Magnetic Materials at High Inductions at Frequencies up to 100 Megacycles**—I. Bady. (pp. 393–394.)

12) **Behaviour of the TE Nodes in Ferrite-Loaded Rectangular Waveguide in the Region of Ferrimagnetic Resonance**—W. J. Crowe. (pp. 397–398.)

13) **Energy Distribution in Partially Ferrite-Filled Waveguides**—J. E. Tompkins. (pp. 399–400.)

14) **Miniaturized Resonant Antenna using Ferrites**—D. M. Grimes. (pp. 401–402.)

15) **Appraisal of Permanent-Magnet Materials for Magnetic Focusing of Electron Beams**—M. S. Glass. (pp. 403–404.)

16) **Origin and Use of Instabilities in Ferromagnetic Resonance**—H. Suhl. (pp. 416–421.)

17) **Microwave Frequency-Conversion Studies in Magnetized Ferrites**—E. N. Skomal and M. A. Medina. (pp. 423–424.)

18) **Spin-Lattice Relaxation Time in Yttrium Iron Garnet**—R. T. Farrar. (pp. 425–426.)

19) **Ferrimagnetic Resonance in Gadolinium Iron Garnet**—B. A. Calhoun, W. V. Smith, and J. Overmeyer. (pp. 427–428.)

20) **Ferromagnetic Resonance in Yttrium Iron Garnet at Low Frequencies**—E. G. Spencer, R. C. LeCraw, and C. S. Porter. (pp. 429–430.)

21) **Microwave Properties of Polycrystalline Rare-Earth Garnets**—M. H. Sirvetz and J. E. Zneimer. (pp. 431–433.)

22) **Temperature Dependence of Microwave Permeabilities for Polycrystalline Ferrite and Garnet Materials**—J. Nemarich and J. C. Cacheris. (pp. 474–476.)

23) **Effect of Cobalt on the Relaxation Frequency of Nickel-Zinc Ferrite**—F. J. Schnettler and F. R. Monforte. (pp. 477–478.)

24) **Switching Properties of Permalloy Cores of Varying Coercivity**—T. D. Rossing and V. J. Korkowski. (pp. 479–480.)

25) **Operating Range of a Memory using Two Ferrite Plate Apertures per Bit**—M. M. Kaufman and V. L. Newhouse. (pp. 487–488.)

26) **Further Development of the Vibrating-Coil Magnetometer**—K. Dwight, N. Menyuk, and D. Smith. (pp. 491–492.)

27) **Improved Torque Magnetometer**—W. S. Byrnes and R. G. Crawford. (pp. 493–495.)

28) **Transparent Ferromagnetic Light Modulator using Yttrium Iron Garnet**—C. S. Porter, E. G. Spencer, and R. C. LeCraw. (pp. 495–496.)

29) **Design of Optimum Inductors using Magnetically Hard Ferrites in Combination with Magnetically Soft Materials**—J. T. Ludwig. (pp. 497–499.)

30) **Pulse Generator based on High Shock Demagnetization of Ferromagnetic Material**—R. W. Kulterman, F. W. Neilson, and W. B. Benedick. (pp. 500–501.)

31) **New Magnetic Core Loss Comparator**—R. E. Tompkins, L. H. Stauffer, and A. Kaplan. (pp. 502–503.)

32) **Skullcap Method for Magnetizing Bowl-Shaped Magnetron Magnets**—F. X. MacDonough. (pp. 506–507.)

33) **Magnetization Reversal by Rotation**—P. R. Gillette and K. Oshima. (pp. 529–531.)

34) **Optical Properties of Several Ferrimagnetic Garnets**—J. F. Dillon, Jr. (pp. 539–541.)

538.221 2157

Domain Wall Motion in Metals—R. W. DeBlois. (*J. Appl. Phys.*, vol. 29, pp. 459–467; March, 1958.) Ferromagnetic domain wall theory is reviewed and a description is given of experimental results of an extension of the Sixtus-Tonks experiment to axial domain wall velocities over 50 km, made possible by use of nearly perfect iron whiskers. Plots of axial velocity vs applied field are nonlinear and in some cases show velocity discontinuities.

538.221 2158

The Effect of Added Titanium and Aluminium on the Magnetic Behaviour of α Ferric Oxide—G. Haigh. (*Phil. Mag.*, vol. 2, pp. 505–520; April, 1957.) The antiferromagnetic transition at −15°C is still observed in synthesized materials for relatively large impurity contents (~10 per cent). The magnetic properties of these materials are compared with those of naturally occurring hematites.

538.221 2159

Magnetic Domains in Manganese-Antimony—R. Perthel and W. Andrä. (*Ann. Physik*, vol. 19, pp. 265–267; May 10, 1957.) Domain patterns in Mn_2Sb and MnSb obtained by the Bitter method are reproduced.

538.221 2160

Magnetic Scattering of Thermal Neutrons of a Ferromagnetic or Antiferromagnetic Material near the Curie Point—M. A. Krivoglaz. (*Doklady Akad. Nauk S.S.S.R.*, vol. 118, pp. 51–54; January/February, 1958.) Mathematical treatment of the thermodynamic theory of magnetic scattering of neutrons.

538.221 2161

Electron-Microscopic Investigation of Magnetic Powder Patterns—W. Schwartze. (*Ann Physik*, vol. 19, pp. 322–328; May 10, 1957.) The relation of magnetic structure to powder pattern is investigated and a method of preparing specimens is described.

538.221 2162

A Magnetic Heating Effect in Oxidized Nickel Wires—C. Schwink. (*Naturwissenschaften*, vol. 44, pp. 485–486; September, 1957.) An application of the electron-optical shadow technique (1515 of 1956) showing the variation of the position of the effective magnetic pole in Ni wires under strain, after heating with and without an alternating field at temperatures below the Curie point.

538.221:537.312.8 2163

Magnetoresistance Coefficients and their Temperature Dependence in Iron and Silicon-Steel—E. Tatsumoto. (*Phys. Rev.*, vol. 109, pp. 658–662; February 1, 1958.)

538.221:538.569.4 2164

Resonant Modes of Ferromagnetic Spheroids—L. R. Walker. (*J. Appl. Phys.*, vol. 29, pp. 318–323; March, 1958.) The spectrum of modes of oscillation of a ferromagnetic spheroid situated in a uniform dc magnetic field is discussed. It is shown that, for samples of normal size, a part of the spectrum consists of magnetostatic modes for which exchange and propagation may be ignored. The analysis presented satisfactorily describes the observed absorption curves.

538.221:538.632 2165

Hall Effect in Ni_3Mn and Fe-Co as a Function of Order—S. Foner, F. E. Allison, and E. M. Pugh. (*Phys. Rev.*, vol. 109, pp. 1129–1133; February 15, 1958.) In Ni_3Mn the values of R_0^* were found to change uniformly from a negative value for a well-ordered sample to a positive value for a disordered sample. This dependence is associated with a Curie-point anomaly. In Fe-Co the values of R_0^* were found insensitive to the degree of atomic ordering and were related to the band structure.

538.221:538.652 2166

A Highly Elastic Magnetostrictive Material—O. Henkel. (*Nachrtech. Z.*, vol. 7, pp. 346–350; August, 1957.) Report of investigations on cylindrical specimens consisting of Fe particles suspended in rubber-like substances.

538.221:538.652:539.37 2167

Plastic Deformation and Magnetostriction—G. Rieder. (*Z. angew. Phys.*, vol. 9, pp. 187–202; April, 1957.) A combined theory covering internal stresses due to plastic deformation and magnetostriction is developed. Its practical application with reference to investigations of magnetic properties [*e.g.*, 1825 of 1957 (Kersten) and 2215 of 1957 (Dietrich and Kneller)] gives satisfactory results. Thirty-two references.

538.221:539.1 2168

Polarization of Positrons and Annihilation in Ferromagnetic Materials—S. S. Hanna and R. S. Preston. (*Phys. Rev.*, vol. 109, pp. 716–720; February 1, 1958.) The angular correlation of two-quantum radiation from annihilation of positrons in ferromagnetic media has been investigated as a function of the direction of magnetization. The observed changes in the correlations are attributed to the polarization of positrons emitted from an unpolarized source.

538.221:[621.318.124+621.318.134 2169

Theory of Magnetostriction and g-factor in

Ferrites—N. Tsuya. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, vol. 8, pp. 161–255; March, 1957.) The theory is based on the Heitler-London approximation. The conclusions are that four mechanisms are mainly responsible for magnetostriction: a) the interplay of spin-orbit interaction with the strain potential; b) classical dipolar interaction; c) the interplay of anisotropic exchange interaction with the strain potential; d) the interplay of intra-spin-spin interaction with the strain potential. The relative importance of the different mechanisms in various ferrites is discussed. Sixty-nine references.

538.221:621.318.124 2170

The Temperature Dependence of the Magnetic Properties of Barium Ferrite—E. Schwabe. (*Z. angew. Phys.*, vol. 9, pp. 183–187; April, 1957.) The characteristics of magnets composed of anisotropic $BaO.6Fe_2O_3$ are investigated. Tests were made on a loud speaker magnet assembly to determine the demagnetizing forces and to derive the means of minimizing the effects of low-temperature storage on operation. See also 506 of 1957 (Sixtus *et al.*).

538.222:538.569.4 2171

Paramagnetic Absorption at Very High Frequencies of some Mn Salts Located in Parallel Fields—A. I. Kurushin. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 938–939; April, 1957.)

538.222:538.569.4 2172

Paramagnetic Absorption at High Frequencies in Gadolinium Salts in Parallel Fields—A. I. Kurushin. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 727–730; April, 1957.) The internal field constant, the isothermal spin relaxation time, and the dependence of the absorption coefficient on the stationary field strength are derived.

548.0:53 2173

Electrical, Optical and Elastic Properties of Diamond-Type Crystals: Part 2—V. S. Mashkevich. (*Zh. Eksp. Teor. Fiz.*, vol. 32, pp. 866–873; April, 1957.) The vibration spectrum for long waves is investigated. Part 1: 3940 of 1957 (Mashkevich and Tolpygo).

621.315.616:539.56 2174

Brittleness in Polyethylene—I. L. Hopkins. (*Bell Lab. Record*, vol. 36, pp. 5–8; January, 1958.) A qualitative description of the molecular structure responsible for brittleness, and of tests designed to measure material characteristics as the rupture point is approached.

MATHEMATICS

517.5 2175

Coefficients for "Decomposition" of Functions into Laguerre-Function Series—J. W. Head and G. M. Oulton. (*Proc. IEE*, pt C, vol. 105, pp. 55–56; March, 1958.) For certain functions a 10-term Laguerre-series approximation may be written down in terms of the value of the function at times proportional to the 10 zeros of the Laguerre function of order 10.

MEASUREMENTS AND TEST GEAR

621.317.3:551.594.6 2176

Atmospheric Radio Noise—J. Harwood and C. Nicolson. (*Electronic and Radio Eng.*, vol. 35, pp. 183–190; May, 1958.) Equipment incorporating recent modifications is described for the measurement of the characteristics of atmospheric noise, with main emphasis on very low frequencies. Parameters measured include the average voltage of the noise envelope, the fraction of time for which various voltages are exceeded by the envelope, and the number of excursions of the envelope above various voltage levels.

621.317.3:621.314.7 2177

A Transistor Tester for the Experimental Lab—R. A. Hempel. (*Electronic Ind.*, vol. 17, pp. 58–61; February, 1958.)

621.317.3:621.314.7 2178

A Method for Measuring Transistor Current Gain at Radio Frequencies—F. J. Hyde. (*J. Sci. Instr.*, vol. 35, p. 115; March, 1958.) A null method of measuring complex values of α at frequencies up to tens of megacycles, using simple apparatus, is described.

621.317.3:621.314.7 2179

Transistor Cut-Off Frequency Measurement—L. C. Cripps. (PROC. IRE, vol. 46, pp. 781–782; April, 1958.) Considerable advantage may be gained by measuring the alpha cut-off frequency by feeding signals to the base with the emitter grounded, since a value nearer to that for the intrinsic cut-off frequency is obtained.

621.317.3:621.396.822:621.372.54 2180

A Tunable Filter for Use in the Measurement of Excess Noise from Local Oscillators—W. P. N. Court. (*Electronic Eng.*, vol. 30, pp. 208–209; April, 1958.) "A method of forming a filter from available microwave components is described. This filter is tunable over a wide band and need not be removed physically from the circuit when filter action is not required."

621.317.3.029.5:621.396.822 2181

Bridge Method of Measuring Noise in Low-Noise Devices at Radio Frequencies—K. S. Champlin. (PROC. IRE, vol. 46, p. 779; April, 1958.) Noise resistances of several hundred ohms can be measured with an over-all error of less than 5 per cent. Errors due to stray coupling and pre-amplifier noise are minimized.

621.317.31(083.74) 2182

Redetermination of the Standard Ampere—(*Tech. News Bull. Nat. Bur. Stand.*, vol. 42, pp. 21–23; February, 1958.) The National Bureau of Standards maintains permanent standards of voltage and resistance from which it is possible to calculate a standard ampere. A comparison with the absolute ampere has recently been made a) using a Pellat-type electrodynamometer and b) using a current balance. The observed change since 1942 when the last comparison was made is so slight that it may be due to experimental error only.

621.317.316:621.372.413.029.64 2183

Measuring Frequency of X-Band Standard Cavities—W. A. Gerard. (*Electronic Ind.*, vol. 17, pp. 66–70; February, 1958.) A flexible method of measuring cavity frequency is described and the determination of stability, temperature compensation, *etc.*, is discussed.

621.317.335.3.029.64 2184

A Spectrometer Method for Measuring the Electrical Constants of Lossy Materials—J. S. Seeley. (*Proc. IEE*, pt C, vol. 105, pp. 18–26; March, 1958.) The analysis of the propagation of a plane wave at oblique incidence through a strip of lossy material is stated, the behavior being completely represented by the use of a complex refractive index and a complex reflection coefficient. A technique is described for measuring these constants by means of a 1-cm parallel-plate spectrometer.

621.317.4 2185

High-Frequency Magnetic Permeability Measurements using Toroidal Coils—R. D. Harrington and R. C. Powell. (PROC. IRE, vol. 46, p. 784; April, 1958.) The results of a previous investigation [3625 of 1954 (Kostyshyn and Haas)] are discussed in relation to the conclusions reached by Schwartz (44 of 1958).

621.317.729:621.3.013.2 2186

An Improved Electromagnetic Analogue—W. T. J. Atkins. (*Proc. IEE*, pt C, vol. 105, pp. 151–154; March, 1958.) A quantitative representation of symmetrical electromagnetic fields is possible enabling dynamic and static effects to be studied.

621.317.75:621.395.625.3 2187

The Magnetic-Tape Oscillograph—W. Reinert. (*Elektrotech. Z.*, vol. 9, pp. 493–498; December 21, 1957.) By means of the process of boundary-displacement recording [1963 of 1952 (Daniels)] oscillograms can be produced on magnetic tape and made visible by the application of iron dust. The design and advantages of such a system are discussed.

621.317.755:621.318.57:621.387 2188

Impulse Voltage Wave Chopping Circuit for Use with a Recurrent Surge Oscilloscope—J. W. Armitage. (*Electronic Eng.*, vol. 30, pp. 186–188; April, 1958.) A hydrogen-filled thyratron is used at voltages up to 2.5 kv.

621.317.755:621-526 2189

An Error-Sampled Sweep-Position Control System—C. H. Knapp, E. Shapiro, and R. A. Thorpe. (*IBM J. Res. Dev.*, vol. 2, pp. 14–35; January, 1958.) Discusses the design of equipment developed for controlling the position of an instantaneous portion of a CRO trace with sufficient precision to permit accurate measurements.

621.317.76:621.395.625 2190

"Wow" and "Flutter"—R. G. T. Bennett and R. L. Currie. (*Electronic and Radio Eng.*, vol. 35, pp. 162–164; May, 1958.) A method of measurement requiring only a stable oscillator and an oscilloscope.

621.317.77 2191

Some Methods of Phase Measurement used in Transfer Function Analysis—D. J. Collins and J. E. Smith. (*Electronic Eng.*, vol. 30, pp. 182–186; April, 1958.) The more conventional systems of measurement are summarized and their limitations are indicated.

621.317.77:621.396.11.029.64 2192

Single Path Phase Measuring System for Three-Centimetre Radio Waves—Thompson and Vetter. (See 2205 below.)

621.317.79.087.9:538.632:537.311.33 2193

A Digital Recording System for Measuring the Electrical Properties of Semiconductors—R. H. A. Carter, D. J. Howarth, and D. H. Putley. (*J. Sci. Instr.*, vol. 35, pp. 115–116; March, 1958.) A modification of the self-balancing potentiometer system described earlier [see 3155 of 1956 (Putley)], whereby measurements can be recorded in digital form on teleprinter tape suitable for feeding directly into an electronic computer.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

621.319.2:535.215 2194

Photoelectrets and the Formation of a Latent Electrophotographic Image—V. M. Fridkin. (*Doklody Akad. Nauk S.S.S.R.*, vol. 118, pp. 273–276; January 11, 1958.) A method similar to xerography using a polarized layer of polycrystalline sulphur 50μ thick is described. A graph shows that the polarization of the electrets after dropping to 40 per cent of its original value remains constant for several hundred hours.

621.384.612 2195

Linear Theory of Synchrotron Oscillations: Part 2—Particle Losses during Acceleration and Tolerance Theory—L. L. Goldin and D. G. Koškarev. (*Nuovo Cimonto*, vol. 6, pp. 286–298;

August 1, 1957.) (In English.) Part 1 of the paper is contained in an article on synchrotron oscillations in strong-focusing accelerators noted in 1839 of 1956. See also 2558 of 1957.

621.384.613 2196
Space-Charge Phenomena in a Betatron—H. W. Schmidt. (*Ann. Physik*, vol. 19, pp. 298–303; May 10, 1957.)

621.385.833 2197
The Use of the Electron-Microscope Shadow Method for Studying the Potential Distribution in *p-n* Junctions—V. N. Vertsner and L. N. Malakhov. (*Doklady Akad. Nauk S.S.S.R.*, vol. 118, pp. 266–268; January 11, 1958.) A resolution of the order of 0.1μ is obtained.

621.398:629.19 2198
Earth-Satellite Telemetry Coding System—R. W. Rochelle. (*Elec. Eng.*, vol. 76, pp. 1062–1065; December, 1957.) Square-hysteresis-loop magnetic materials are used with transistors in magnetically coupled multivibrators. The encoder operates on a time sharing principle and controls AF multivibrators. The length of time these are on, the frequency of oscillation, and the length of time between oscillation periods give the required channels of information with no dead time in the transmitted signal. See also 1844 of 1958 (Matthews).

PROPAGATION OF WAVES

621.396.11 2199
On the Propagation of the Electromagnetic Waves in an Inhomogeneous Atmosphere: Part 2—Y. Nomura and K. Takaku. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, vol. 8, pp. 61–96; September, 1956.) The integral representation for electromagnetic wave propagation (see Part 1: 250 of 1957) is transformed into the sum of residues at poles, and the intensity of diffracted waves in the geometric-optical shadow is calculated. The inhomogeneous atmosphere causes a marked change in the intensity of the diffracted waves as compared with the homogeneous atmosphere. Expressions are derived for diffracted waves at the boundaries where the medium changes continuously, as well as at the ordinary boundaries where the medium changes discontinuously. For a preliminary report of the work, see 545 of 1956.

621.396.11 2200
June—Vertical and Oblique Incidences—R. Gea Sacasa. (*Rev. Telecomunicación, Madrid*, vol. 11, pp. 2–13; September, 1957.) (In Spanish and English.) A further series of comparisons between IFRB forecasts and those based on the Gea method. See also 1241 of 1958.

523.164.3:621.396.11 2201
Propagation of Radio Waves from Cosmical Sources—Chvojková. (See 2083.)

621.396.11:551.510.535 2202
Single-Hop Propagation of Radio Waves to a Distance of 5300 km—E. Warren and E. L. Hagg. (*Nature, London*, vol. 181, pp. 34–35; January 4, 1958.) Single-hop propagation between Ottawa and Slough associated with reflection at apparent heights of 600–900 km, was observed, *e.g.*, at 1800 GMT on September 11, 1957 for frequencies of 27–33 mc. Records indicate that the one-hop mode occurs with the same reliability as the two and three-hop modes at times between 1200 and 2020 GMT for similar distances and frequencies.

621.396.11.029.45:551.510.53 2203
Observations of Magneto-ionic Duct Propagation using Man-Made Signals of Very Low Frequency—R. A. Helliwell and E. Gehrels. (Proc. IRE, vol. 46, pp. 785–787; April, 1958.) Echoes of $\frac{1}{2}$-second pulse signals from station NSS in Annapolis, Maryland, on 15.5 kc have been detected with delays up to nearly 1 second at Cape Horn, South America, providing a controlled test of the Eckersley-Storey theory of "whistlers" (see, *e.g.*, 142 of 1954). When observed, the echoes were 10–30 db weaker than the direct wave, and were subject to systematic fading and splitting.

621.396.11.029.62/.63 2204
Guglielmo Marconi and Communication beyond the Horizon—G. A. Isted. (*Point to Point Telecommun.*, vol. 2, pp. 5–17; February, 1958.) Marconi's work on propagation at 30 and 600 mc is reviewed. He showed conclusively that communication could be achieved beyond optical path limits using reflection in the lower atmosphere. His apparatus is described which, although primitive, seemed very effective.

621.396.11.029.64:621.317.77 2205
Single Path Phase Measuring System for Three-Centimetre Radio Waves—M. C. Thompson, Jr. and M. J. Vetter. (*Rev. Sci. Instr.*, vol. 29, pp. 148–150; February, 1958.) A practical system is described for making single-path phase measurements at X-band frequencies over ranges up to about 20 miles with instrumental noise of the order of a fraction of one degree. The techniques for obtaining the necessary transmitter frequency stability of $1:10^9$ are described. The use of such techniques to form a simple microwave repeater system with power gain of the order of 50 db is discussed.

621.396.8 2206
Asymmetry in Long-Distance W/T Circuits—A. M. Humby. (*Wireless World*, vol. 64, pp. 204–207; May, 1958.) An analysis has been made of hourly records of reception conditions on the Montreal-Melbourne circuit for the period 1935–1955, for which both short and long paths are mainly over sea. A seasonal asymmetry is noticed, resulting in a significant fall in performance in the direction which entails reception in local summer. No sharply defined hour of onset of this asymmetry is evident, as was reported for transequatorial land routes [see 3208 of 1956 (Humby and Minnis)].

RECEPTION

621.376.2/.3:621.372.5 2207
The Change of Amplitude Modulation into Frequency Modulation Caused by some Limiter Circuits—E. De Castro and E. Stanghellini. (*Alta Frequenza*, vol. 26, pp. 530–544; October, 1957.) Simple formulas for calculating output phase deviation corresponding to a given input modulation depth are derived. See also 2879 of 1956 (De Castro).

621.376.23:621.372.54 2208
Detection of Pulsed Signals in Noise—H. S. Heaps and A. T. Isaacs. (*Electronic and Radio Engr.*, vol. 35, pp. 190–193; May, 1958.) An analysis of the optimum design of a low-pass filter for the detection of rectangular pulses in a background of white noise. Results are shown graphically.

621.396.62:621.376.3:621.314.7 2209
A Transistorized 150-Mc/s F.M. Receiver—W. J. Giguere. (Proc. IRE, vol. 46, pp. 693–699; April, 1958.) A completely transistorized experimental fm communication receiver is described. Diffused-base transistors are used and its frequency range is 152–174 mc. Power consumption is 130 mw and adjacent-channel selectivity is better than 70 db for 60-kc channel spacing.

621.396.621.54 2210
Variable-Selectivity I. F. Stages in Communication Receivers—J. B. Dance. (*Short Wave Mag.*, vol. 15, pp. 572–578; January, 1958.) Design considerations for the construction of an IF unit of variable selectivity for use with an existing receiver.

621.396.662 2211
Sensitive Tuning Indicators—R. Oliver. (*Wireless World*, vol. 64, pp. 235–236; May, 1958.) A note on circuit arrangements for improving the performance of a "magic-eye" tuning indicator, particularly by connecting it to an appropriate screen-grid line or, in the case of fm receivers, in the limiter anode circuit.

621.396.82 2212
Radio Interference: Part 1—Introduction—D. A. Thorn. (*P.O. Elec. Engr. J.*, vol. 50, pt 4, pp. 226–227; January, 1958.) An introduction to a series of six articles which will present a general survey of the subject with emphasis on the telecommunications aspects.

621.396.82 2213
Radio Interference: Part 2—The Post Office Radio Interference System—G. A. C. R. Britton. (*P.O. Elec. Engr. J.*, vol. 50, pt 4, pp. 227–230; January, 1958.) The organization for dealing with interference complaints, the apparatus, and methods used for tracing the interference are described. The main types of apparatus that cause the interference are listed.

621.396.82:621.376.3 2214
Theory of Stronger-Signal Capture in F.M. Reception—E. J. Baghdady. (Proc. IRE, vol. 46, pp. 728–738; April, 1958.) The amplitude limiter in fm receivers spreads out the spectrum of the disturbing signals over a range which is often much greater than that of the message modulation. Hence limiting followed by filtering can suppress disturbances considerably ahead of the discriminator stage.

STATIONS AND COMMUNICATION SYSTEMS

621.391 2215
On Nonuniform Sampling of Bandwidth-Limited Signals—J. L. Yen. (IRE Trans. on Circuit Theory, vol. CT-3, pp. 251–257; December, 1956. Abstract, Proc. IRE, vol. 45, p. 717; May, 1957.)

621.391 2216
Definition of "Bandwidth" and "Time Duration" of Signals which are Connected by an Identity—D. G. Lampard. (IRE Trans. on Circuit Theory, vol. CT-3, pp. 286–288; December, 1956. Abstract, Proc. IRE, vol. 45, p. 717; May, 1957.)

621.391:519.2 2217
Systems Analysis of Discrete Markov Processes—R. W. Sittler. (IRE Trans. on Circuit Theory, vol. CT-3, pp. 257–266; December, 1956. Abstract, Proc. IRE, vol. 45, p. 717; May, 1957.) See also 1227 of 1957 (Huggins).

621.391:519.2 2218
Limiting Conditions on the Correlation Properties of Random Signals—G. Kraus and H. Pötzl. (IRE Trans. on Circuit Theory, vol. CT-3, pp. 282–285; December, 1956. Abstract, Proc. IRE, vol. 45, p. 717; May, 1957.)

621.391:621.376.2 2219
The Theory of Analytic Band-Limited Signals Applied to Carrier Systems—J. R. V. Oswald. (IRE Trans. on Circuit Theory, vol. CT-3, pp. 244–257; December, 1956. Abstract, Proc. IRE, vol. 45, p. 717; May, 1957.)

621.391:621.376.5 2220
A Study of Rough Amplitude Quantization by means of Nyquist Sampling Theory—B. Widrow. (IRE Trans. on Circuit Theory, vol. CT-3, pp. 266–267; December, 1956.

Abstract, PROC. IRE, vol. 45, p. 717; May, 1957.)

621.391:621.396.822 2221

The Penetration of Noise into Communication Channels in the Light of Information Theory—P. Neidhardt. (*Nachrtech. Z.*, vol. 7, pp. 419–422; September, 1957.) The reduction of information content by noise is discussed in terms of communication theory particularly as derived by Shannon.

621.396.1 2222

On Channel Spacing—(*Point to Point Telecommun.*, vol. 2, pp. 19–23; October, 1957.) Channel separations of 50 kc are called for in the 80 and 160-mc bands in the United Kingdom. Some of the problems of this and possible smaller separations are discussed briefly.

621.396.2.029.6 2223

Standardizing Microwave Communication Systems—T. Clark. (*Electronic Ind.*, vol. 17, pp. 50–54; February, 1958.) Suggestions by a committee of the Electronic Industries Association for standardization and definition of terms for microwave communication systems.

621.396.3 2224

Automatic Error Correction on H. F. Telegraph Circuits—P. R. Keller. (*Point to Point Telecommun.*, vol. 2, pp. 25–48; February, 1958.) A seven-character three-mark code based on the Van Duuren system recommended by the CCIT is described with respect to error correction. The techniques involved and the basic block diagrams for circuitry are given. Emphasis is placed on the need for fully electronic equipment and an appendix is given on cold-cathode tube circuits.

621.396.3:621.376.4 2225

Kineplex, a Bandwidth-Efficient Binary Transmission System—R. R. Mosier and R. G. Clabaugh. (*Commun. & Electronics*, no. 34, pp. 723–727; January, 1958. Discussion, pp. 727–728.) Description of a high-capacity phase-shift data transmission system which will operate in a single telephone voice band of standard quality or equivalent, and will accept at its input, with suitable conversion, binary data from any source.

621.396.41:621.376.32 2226

F.M. Exciter for Sight or Scatter Systems—A. E. Anderson and H. D. Hern. (*Electronics*, vol. 31, pp. 148–151; March 14, 1958.) The exciter accepts multichannel output of the telephone terminal equipment as a modulating signal and produces an output power of 15 watts from 700 to 1200 mc, and 8 watts from 1700 to 2400 mc. The unit handles 132 voice channels in addition to an order-wire system.

621.396.41:621.396.65 2227

6000-Mc/s Radio Relay System for Broad-Band Long-Haul Service in the Bell System—M. B. McDavitt. (*Commun. & Electronics*, no. 34, pp. 715–722; January, 1958.) The system is designed to transmit telephone messages or color television signals over distances up to 4000 miles. Objectives and requisites of the system and its principal features are described. Details are given of some of the more interesting new components.

621.396.5:621.396.65 2228

An Introduction to "Rural Radio"—C. B. Wooster. (*Point to Point Telecommun.*, vol. 2, pp. 24–28; October, 1957.) Techniques are discussed which permit the full integration of single-channel VHF links with line telephone systems in areas where it is impracticable to erect landlines. The equipment is fairly simple and not very difficult to maintain. A wide range of signaling facilities is available. See 2294 of 1957.

621.396.65 2229

Convention on Radio Links—(*Alta Frequenza*, vol. 26, pp. 321–576; October, 1957.) First of a number of issues covering the proceedings of a convention held in Rome, June 5–8, 1957. Abstracts of some of the papers are given individually; titles of others are as follows:

1) **The Trends of Telecommunications as Affected by Solid-State Electronic Instrumentation**—M. J. Kelly. (pp. 333–345. In English. Discussion, pp. 346–348.)
2) **Propagation with Horizontal and Vertical Polarization over the Paths Portofino-Monte Beigua and Portofino-Monte S. Nicolao-P. Quarta.** (pp. 404–414.)
3) **Tests of Radio Propagation beyond the Horizon over the Mediterranean**—L. Niccolai. (pp. 415–418.)
4) **Radio Link Italy—Spain for Tropospheric Propagation beyond the Horizon**—L. Pallavicino. (pp. 419–427.)
5) **6000-Mc/s Radio Relay System for Broad-Band Long-Haul Service in the Bell System**—M. B. McDavitt. (pp. 428–446. In English.) See 2227 above.
6) **Some Problems Experienced in the Establishment of Radio Link Systems**—A. W. Montgomery. (pp. 447–462. In English.)
7) **The Planning of Tropospheric Scatter Systems**—K. W. Pearson. (pp. 463–467. In English.)
8) **Kineplex**—P. J. Icenbice and S. R. Crawford. (pp. 468–473. In English.) See 2225 above.
9) **Calculation of the Intermodulation Noise in F.M. Radio Links for Telephony**—B. Peroni. (pp. 502–529.)
10) **Possibilities and Limitations in the Use of Radio Links comprising Demodulation-Type Repeaters**—R. B. Chaux. (pp. 545–549. In French.)

621.396.65 2230

Radio Link Milan-Palermo for Sound and Telephony—B. Peroni. (*Alta Frequenza*, vol. 26, pp. 371–388; October, 1957.) Detailed description of the relay system for transmitting the television sound broadcasts of the RAI. Four two-way high-quality sound channels and 12 speech channels are available, and particular attention has been given to the reduction of cross-modulation and noise. For details of the television link, see 2254 below.

621.396.65:621.396.43:621.396.8 2231

The Calculation of Distortion Factors and Noise due to various Types of Distortion in Multichannel F.M. Radio Links—H. Marko. (*Nachrtech. Z.*, vol. 10, pp. 450–457; September, 1957.) The discussion is based on the CCIR recommendations for radio-link systems. See also 2232 below.

621.396.65:621.396.43:621.396.822 2232

The Distribution of Noise in Radio Links for Multichannel Telephony Transmission—W. Mansfeld. (*Nachrtech. Z.*, vol. 7, pp. 329–335 and 466–472; August and October, 1957.) The characteristics are outlined of a hypothetical 2500-km radio link intended as reference system and based on CCIR specifications. The various types of noise, their origin and elimination are discussed.

621.396.65:621.396.822 2233

Thermal Noise in Multisection Radio Links—B. B. Jacobsen. (*Proc. IEE*, pt C, vol. 105, pp. 139–150; March, 1958.) An investigation of methods for calculating thermal noise in a long radio link when the individual sections are subject to fading. A technique is described for combining the fading statistics from individual sections to obtain the first three moments for the over-all circuit. This is expressed in terms of an "augmented log-normal distribution," which can readily be translated into the distribution of thermal noise in the complete path. A method is described for synthesizing an over-all circuit distribution from a number of sections with similar fading statistics.

621.396.931:621.395.3 2234

The Probability of Success of a Call over the Swiss Network for Calling Motor Vehicles—E. Wey. (*Tech. Mitt. PTT*, vol. 35, pp. 387–395; September 1, 1957.) Description of the system (see 1159 of 1955) and report on the efficiency of the service based on country-wide field-strength measurements.

SUBSIDIARY APPARATUS

621-52 2235

A Note on the Evaluation of the Response of a Nonlinear Element to Sinusoidal and Random Signals—J. L. Douce. (*Proc. IEE*, pt C, vol. 105, pp. 88–92; March, 1958.) A method is developed based upon a mathematical technique described by Lewis (*Trans. AIEE*, vol. 73, pt I, pp. 693–700; 1954) which is particularly useful for the analysis of nonlinear control systems. Simple cursors may be constructed to determine the effective gain of the nonlinear unit. The application to hysteretic nonlinearities and the response to random signals is illustrated.

621-52:681.142 2236

Statistical Design Theory for Strictly Digital Sampled-Data Systems—S. S. L. Chang. (*Commun. & Electronics*, no. 34, pp. 702–708; January, 1958. Discussion, pp. 708–709.) Present design theories are based on system response to inputs of known shape, and little attention is given to situations in which only the statistical properties of the inputs are known. The basis of a statistical design theory is presented and applied to the optimum design of a strictly digital system. The new theory forms a close parallel to Wiener's theory of optimum filtering and prediction, and its various manifestations in applications to continuous feed-back control systems.

621-526 2237

A Correlation between the Transient and Frequency Responses in Servomechanisms—Z. J. Jelonek and G. I. Boomer. (*J. Brit. IRE*, vol. 18, pp. 101–114; February, 1958.) Statistical evidence is used to relate time and frequency-response parameters. These empirical relations, together with a new theoretical relation for the delay time, enable the step response to be sketched, given the open-loop response. Some nontypical closed-loop responses may be broken down into two subtransient step responses which are separately determinable.

621-526:519.2 2238

Fundamental Equations for the Application of Statistical Techniques to Feedback-Control Systems—G. A. Biernson. (IRE TRANS. ON AUTOMATIC CONTROL, vol. AC-2, pp. 56–78; February, 1957. Abstract, PROC. IRE, vol. 45, p. 572; April, 1957.)

621-526:621.375.4 2239

Direct-Drive Amplifier for Two-Speed Servos—B. E. Orr. (*Electronics*, vol. 31, pp. 146–147; March 14, 1958.) A five-transistor servo amplifier drives a standard motor without using an output transformer. For a two-speed system the amplifier contains a switching circuit incorporating Zener diodes, and a three-stage feedback network.

621.311.68 2240

Automatic Power Plant for Telecommunications Installations—K. J. Bladon. (*Point to Point Telecommun.*, vol. 2, pp. 5–18; October, 1957.) The development of multichannel radiotelephone services capable of unattended operation for long periods has led to the need for automatic generators of electric power. Some of the factors in the design of Diesel power plants are considered. Both mains standby and dual alternator systems are discussed.

621.314.22 2241

Hot Transformers—(*Engineering, London*, vol. 184, p. 623; November 15, 1957.) Brief note on two experimental types of transformer designed for operation at 500°C. One, housed in an evacuated stainless-steel case, is rated 100 va at 1600 cps, the other is of open construction with a nominal rating of 50 va at 50 cps.

621.314.58:621.373.431.1 2242

Magnetic Inverter uses Tubes or Transistors—C. H. R. Campling. (*Electronics*, vol. 31, pp. 158–161; March 14, 1958.) A means of producing ac from dc. The collector and emitter coil windings of the "on" transistor of a multivibrator are differentially connected across the input voltage so that the drive winding partially determines the frequency of oscillation.

TELEVISION AND PHOTOTELEGRAPHY

621.397.5:535.623 2243

The Analogous Frequency of the Colour Sub-carrier in an Adaptation of the N.T.S.C. System to the 625-Line C.C.I.R. Standard—E. Schwartz. (*Rundfunktech. Mitt.*, vol. 1, pp. 191–195; October, 1957.) The various proposals for a suitable color subcarrier frequency are discussed. Calculation leads to a value of 4.17 ±0.04 mc, so that 4.2109375 or 4.1015625 mc could be chosen. A symmetrical-sideband system can be adopted if a low subcarrier frequency is used. See also 1878 of 1956 (Below and Schwartz).

621.397.5:621.395.625.3 2244

Television Tape Recorder—(*Electronic and Radio Eng.*, vol. 35, pp. 193–195; May, 1958.) In the "vision electronic recording apparatus" of the BBC, a 20½-inch diameter reel of half-inch magnetic tape played at 200 inch per second provides 15 minutes of program. Three tracks are used simultaneously, two for the video signal and one for sound. The modulation system used, and some electrical and mechanical details, are described.

621.397.5:621.395.625.3 2245

Television Recording on Magnetic Tape by the Ampex Method—H. J. V. Braunmühl and O. Schmidbauer. (*Rundfunktech. Mitt.*, vol. 1, pp. 186–190; October, 1957.) See also 294 of January (Ginsburg).

621.397.6:621.314.7 2246

The Application of Transistors to Television—J. N. Barry and A. E. Jackets. (*J. Television Soc.*, vol. 8, pp. 318–334; October–December, 1957.) After a review of recent progress towards increasing the frequency and power range of transistors, their application to each of the main television circuits is discussed in detail with circuit diagrams. A short note on their suitability in color television apparatus is included, and possible future applications are discussed.

621.397.61.029.63 2247

B.B.C. Band-V Experimental Television Transmission—(*Engineer, London*, vol. 204, pp. 797–798; November 29, 1957.) Details of the transmitter equipment installed at Crystal Palace for tests in the range 470–960 mc, but particularly at a vision frequency of 654.25 mc. An initial series of tests on 405 lines will be followed by 625-line transmissions.

621.397.62:535.623:621.3.049.75 2248

Etched I.F. Amplifier Pares Colour TV Cost—L. Ruth. (*Electronics*, vol. 31, pp. 135–137; March 14, 1958.) Vane-tuned inductances and rejection traps are etched on the same board as the wiring of a 41-mc IF strip. Design requirements, construction details and performance data are given.

621.397.62:621.314.7 2249

Transistor Television Circuits: Part 2—Scan Output Stages, Video and Signal-Frequency Amplifiers—J. N. Barry and G. W. Secker. (*Wireless World*, vol. 64, pp. 231–235; May, 1958.) Circuit details are given of a complete frame output section for a 17-inch receiver, and the operation of transistors in linear RF amplifiers is discussed. Part 1: 1889 of 1958.

621.397.62.029.63:621.372.632 2250

Television Reception on Band V—H. N. Gant. (*Wireless World*, vol. 64, pp. 244–246; May, 1958.) A converter for use with band-III receivers is described, which incorporates an UHF amplifier stage. A new type of tube with special electrode construction and low anode current is used and a noise factor of about 11 db for the converter is achieved.

621.397.621.2.002.1:535.623 2251

Development Problems of Colour-Television Picture Tubes—I. Bornemann. (*Nachrtech. Z.*, vol. 7, pp. 399–404; September, 1957.) The differences in afterglow duration of phosphors for tricolor cathode ray tubes and their effect on color fringing are considered. See also 2930 of 1957.

621.397.7 2252

The New B.B.C. Television Studios in London—A. N. Thomas. (*Rundfunktech. Mitt.*, vol. 1, pp. 169–180; October, 1957.) Illustrated descriptions are given of the lay-out and the equipment of the Riverside studios [see 609 of 1958 (Nickels and Grubb)], the television theater at Shepherds Bush in operation since July, 1957, and the White City television center under construction.

621.397.7 2253

The New Television Studios of the R.A.I. in Rome—L. Sponzilli. (*Rundfunktech. Mitt.*, vol. 1, pp. 181–185; October, 1957.)

621.397.7 2254

Television Radio Link Milan—Palermo—F. Carassa. (*Alta Frequenza*, vol. 26, pp. 349–370; October, 1957.) The wide-band relay link described is 1640 km long and comprises 21 repeater and terminal stations.

621.397.7 2255

The Microwave Television Link Italy—Sardinia—F. Carassa. (*Alta Frequenza*, vol. 26, pp. 389–403; October, 1957.) The system described consists of an oversea link of 238 km length. As a result of propagation tests (1890 of 1957) a carrier frequency of 940 mc, that of the main television network, was chosen; this provides a large bandwidth and facilitates connection to the relay system on the mainland (2254 above).

621.397.7:621.3.018.78 2256

Waveform Distortion in F.M. Television Radio Links—F. Carassa. (*Alta Frequenza* vol. 26 pp. 474–501; October, 1957.) The waveform distortion due to small sinusoidal deviations from the ideal flat amplitude and group-delay response curves is interpreted in terms of echoes. The effect of various response conditions on the CCIR test waveform is investigated. Distortion can be reduced considerably, by means of a video-frequency low-pass filter following the demodulator.

621.397.8 2257

The Influence of Multipath Propagation on the Carrier-Frequency Spectrum of the Television Signal—K. Bernath and H. Brand. (*Tech. Mitt. PTT*, vol. 35, pp. 401–412; October 1, 1957.) The case of ideal two-path reception is analyzed and the principal factors controlling the shape of the received spectrum are discussed. Experimental results are compared with computed spectra of received signals for two transmitters and various paths, including a case of almost ideal reflection from an intervening lake, and reception via a long montainous path. The difficulties likely to arise in the reception of color television signals are examined in the light of statistical investigations of reception in built-up areas.

621.397.8:535.623 2258

The Definition of Picture Quality in Monochrome and Colour Television—P. Neidhardt. (*Nachrtech. Z.*, vol. 7, pp. 389–398; September, 1957.) Detailed discussion of the means of assessing picture quality in clearly definable terms. By analogy with information theory the concept of detail entropy is derived and its application extended to the assessment of color image quality. Twenty-nine references.

TRANSMISSION

621.396.61:621.314.7 2259

Transistor Transmitter—L. F. Shaw. (*Wireless World*, vol. 64, pp. 241–243; May, 1958.) A portable all-transistor amateur transmitter for the 160-m band is described.

TUBES AND THERMIONICS

621.314.63:546.28 2260

Determination of the Diffusion Length L and the Inversion Density n_i from the Forward Characteristics of Silicon Alloy Junction-Type Rectifiers—A. Herlet. (*Z. angew. Phys.*, vol. 9, pp. 155–158; April, 1957.) A method of determining L and n_i is derived on the basis of a comparison of experimentally obtained characteristics with theory. See also 598 of 1956.

621.314.63.029.65:546.28 2261

Wafer-Type Rectifiers for Millimetre Waves—W. M. Sharpless. (*Bell Lab. Record* vol. 36, pp. 21–24; January, 1958.) See 1607 of 1957.

621.314.632.209.64:546.681.19 2262

A Gallium Arsenide Microwave Diode—D. A. Jenny. (PROC. IRE, vol. 46, pp. 717–722; April, 1958.) The semiconductor properties of GaAs, particularly the high electron mobility and forbidden band gap, besides favorable point-contact rectification characteristics, are of interest for microwave diode applications. Theoretically and experimentally GaAs is potentially superior to Ge and Si in point-contact diodes. Its mixer conversion loss is less, and it should operate at higher temperatures.

621.314.7 2263

Developments in Transistor Electronics—L. B. Valdes. (*J. Electronics Control*, vol. 4, pp. 1–16; January, 1958.) The design theory of point-contact and junction transistors is reviewed. Selected examples illustrate the small-signal and large-signal properties of junction transistors. These phenomena are related to the theory of p-n junctions.

621.314.7 2264

On Carrier Accumulation, and the Properties of Certain Semiconductor Junctions—J. B. Gunn. (*J. Electronics Control*, vol. 4, pp. 17–50; January, 1958.) In a semiconductor near an electrode boundary a situation may arise in which minority carriers are drawn by the electric field towards the boundary, across which they can pass only with difficulty. Carrier accumulation will then develop. It is shown theoretically that where a junction exists between relatively pure and relatively impure regions of a semiconductor, carrier accumulation should be observable in the lightly doped section. Such a junction is used in a class of devices known as conductance transistors, which can have a large current gain. This gain is calculated in a particular case, together with emitter and collector impedances.

621.314.7 2265

Effects of Low Temperatures on Transistor Characteristics—A. B. Credle. (*IBM J. Res. Dev.*, vol. 2, pp. 54–71; January, 1958.) Describes measurements on a group of similar *p-n-p* alloy-junction transistors made between 0.5 and 5 mc and from room temperature down to that of liquid N_2, leading to simple equivalent networks. Grounded-emitter pulse tests show that, for a given output pulse current, rise time decreases with temperature, and at the temperature of liquid N_2 rise time decreases as the output current pulse increases. A 30-mw, 3-mc transistor can then deliver a 1-a current pulse with a rise time of a few tenths of a microsecond, with a grounded-emitter gain of about 20. Theoretical expressions for the effect of temperature on transistor parameters are evaluated. See also 4041 of 1957 (Uda.)

621.314.7:621.317.3 2266

A Transistor Tester for the Experimental Lab.—Hempel. (See 2177.)

621.314.7:621.317.3 2267

A Method for Measuring Transistor Current Gain at Radio Frequencies—Hyde. (See 2178.)

621.314.7:621.317.3 2268

Transistor Cut-Off Frequency Measurement—Cripps. (See 2179.)

621.314.7:621.318.57 2269

Controlled Saturation in Transistors and its Application in Trigger Circuit Design—Moody. (See 1995.)

621.314.7:621.397.6 2270

The Application of Transistors to Television—Barry and Jackets. (See 2246.)

621.383.032.217.2 2271

Interference Photocathodes of Increased Yield with Freely Variable Maximum Spectral Response—K. Deutscher. (*Naturwissenschaften*, vol. 44, pp. 486–487; September, 1957.) A layer of $SbCs_3$ covers a wedge of MgF_2 mounted an ac mirror. By investigating this interference system under monochromatic light the relation of photocurrent to the reflecting power of the system was determined. The photoelectric yield is a maximum where the reflection is reduced to a minimum.

621.385.029.6 2272

Stability of an Electron Beam on a Slalom Orbit—J. S. Cook, W. H. Louisell, and W. H. Yocom. (*J. Appl. Phys.*, vol. 29, pp. 583–587; March, 1958.) A study of an electrostatic method of focusing an electron beam in a traveling-wave tube in which the beam traverses a slalom-like orbit between the wires of the slow-wave structure. The equations of motion are solved to find initial conditions for stable orbits. Good agreement is found between the computed and measured current transmitted.

621.385.029.64:537.533:621.375.9 2273

Parametric Amplification of Space-Charge Waves—W. H. Louisell and C. F. Quate. (Proc. IRE, vol. 46, pp. 707–716; April, 1958.) The principle of using a variable reactance to obtain gain can be applied to an electron beam by modulating it at a frequency of twice the signal frequency. The normal space-charge wave breaks into two parts—one growing and one attenuated; either the "slow" or "fast" wave can be amplified. The beam can then be coupled to a slow-wave circuit, in which the "fast" wave can be amplified again. Noise theorems for previous microwave amplifiers deal with the "slow" wave and no not apply here. Lower values for the noise figure should in principle be achieved. See also 1606 of May (Bridges).

621.385.032.213.13 2274

The Conductivity of Oxide Cathodes—G. H. Metson. (*Proc. IEE*, pt C, vol. 105, pp. 183–188 and 189–195; March, 1958.)

Part 3—**Movements of Electrolytic Oxygen in a Conventional Diode System**—Negative oxygen ions from the cathode, if not completely absorbed at the anode, may return to the cathode and produce reactions analogous to the electrolytic actions of the S-type assembly.

Part 4—**Electron Transfer Mechanisms**—At temperatures between 850 and 1100° K all the electrons are thermionically emitted at the cathode-core surface and pass through the vacuum interstices of the oxide-cathode matrix; their energy is dissipated uniformly by successive non-elastic collisions with solid oxide particles. Between 290 and 600° K, the mechanism is one of solid-state semiconduction and no thermionic emission takes place. These deductions from experimental results agree with the hypothesis of Loosjes and Vink (3208 of 1950).

Parts 1 and 2: 4072 and 4073 of 1957. Please note change of U.D.C. number.

If FAST SWITCHING is your need and available germanium types won't meet temperature and reliability requirements . . .

SWITCH to SILICON

ACTUAL SIZE

MILITARY TYPES

Silicon Computer Diodes

1N663
1N662
1N643

A definite break-through of the inherent temperature limitations of germanium is provided by these outstanding new Silicon Diffusion Computer Diodes. They switch as fast as the best germanium types...and at temperatures to 150°C!

They combine fast switching with high conductance and high break-down voltage with high temperature operation . . . plus PSI "Built-in-Reliability."

These three related military types can replace all germanium diodes in computers of advanced design where high reliability performance *at high temperatures* must be sustained without compromise.

Look at these outstanding specifications!

		EIA TYPE	Minimum Saturation Voltage (volts) @ 100 µA	Minimum Current Forward @ + 1.0v	Maximum Reverse Current (µA)		Reverse Recovery Characteristics	
					25°C	100°C	Reverse Resistance (ohms)	Maximum Recovery Time (µs)
HI-CONDUCTANCE	Mil-E-1/1140 (Sig C)	1N663	100	100	5(75v)	50(75v)	200K	0.5
GENERAL PURPOSE	Mil-E-1/1139 (Sig C)	1N662	100	10	1(10v) 20(50v)	20(10v) 100(50v)	100K	0.5
HIGH VOLTAGE	Mil-T-12679/39 (Sig C)	1N643	200	10	.025(10v) 1(100v)	5(10v) 15(100v)	200K	0.3

Detailed specifications, ratings and curves available on request.

Distributors:

ALLIED RADIO
Chicago, Illinois
ALMO RADIO COMPANY
Philadelphia 7, Pennsylvania
CRAMER ELECTRONICS, INC.
Boston 16, Massachusetts
ELECTRONIC SUPPLY CORP.
Pasadena, California
ELECTRONIC INDUSTRIAL SALES
Washington 1, D. C.
PEERLESS RADIO DISTRIBUTORS, INC.
Jamaica 33, New York
PENINSULA TV AND RADIO SUPPLY
San Jose, California
WHOLESALE RADIO PARTS COMPANY
Baltimore 1, Maryland

Write for full information on the entire line of PSI silicon and germanium diodes, silicon rectifiers and PSI voltage-variable capacitors (VARICAP). Production quantity delivery on all types.

TM

Pacific Semiconductors, Inc.

10451 West Jefferson Boulevard, Culver City, California
NEW YORK – 2079 Wantagh Ave., Wantagh, Long Island, N. Y.
CHICAGO – 6957 W. North Ave., Oak Park, Illinois
SEATTLE – Administration Bldg., Boeing Field, Seattle, Wash.
EXPORT DEPARTMENT – 431 Fifth Ave., New York 16, N. Y.

© 1958 Pacific Semiconductors, Inc.

Amperex
6939
MADE IN US

It's the

EXTRAS

that make a GOOD tube

GREAT!

Amperex®
6939

MINIATURE UHF TWIN TETRODE

with these **Amperex EXTRAS:**

- frame grid construction
- 5 watts total anode dissipation in miniature envelope
- 5½ watts useful power in load (ICAS)
- maximum ratings to 500 Mc
- gold-plated grid for low grid emission

OPERATING CONDITIONS, AMPLIFIER, CLASS C, FM

	CCS	ICAS
Frequency	500	500 Mc
Plate Voltage	180	200 volts
Screen Grid Voltage	180	200 volts
Control Grid Bias	—20	—20 volts
Plate Current	2x27.5	2x30 ma
Screen Grid Current	11	13 ma
Control Grid Current	2x1	2x1 ma
Driving Power	1.0	1.0 watts
Plate Input Power	2x5	2x6 watts
Plate Dissipation	2x2.1	2x2.25 watts
Screen Grid Dissipation	2	2.6 watts
Output Power	5.8	7.5 watts
Useful Power in Load	4.5	5.5 watts

Other **Amperex** *replacement favorites:*

5894	High-sensitivity VHF/UHF twin tetrode; 40 watts anode dissipation
6360	High-sensitivity VHF/UHF twin tetrode; 14 watts anode dissipation
6146	High-sensitivity beam power tube
866AX	Mercury vapor rectifier

ask your distributor about extra-quality **Amperex** *replacement tubes*

Amperex ELECTRONIC CORP.
230 Duffy Avenue, Hicksville, L. I., N. Y.

Membership

The following transfers and admissions have been approved and are now effective:

Transfer to Senior Member

Alfie, C. L., Alamogordo, N.M.
Barnes, R. E., Algona, Iowa
Carlson, H. A., Torrance, Calif.
Castenholz, F. E., Muskegon, Mich.
Cole, E. J., Fullerton, Calif.
Cory, W. E., Sherman Oaks, Calif.
Crone, J. L., Kensington, Md.
Davidson, G. K., Montreal, P.Q., Canada
Elam, T. W., Littleton, Colo.
Fernane, J., Richards-Gebaur AFB, Mo.
Fewer, D. R., Dallas, Tex.
Gardner, F. M., Orange, Calif.
Gladding, E. B., Norfolk, Va.
Harvey, R. A., Richland, Wash.
Jenkins, E. W., Jr., Midland, Tex.
Jenkins, E. E., Ottawa, Ont., Canada
Johnston, W. A., Jr., Roslyn Heights, N.Y.
Kelly, B. A., Fort Worth, Tex.
Knight, M. B., West Caldwell, N.J.
Lanier, R. E., Arlington, Tex.
Larson, R. E., Boulder, Colo.
Logue, J. C., Poughkeepsie, N.Y.
Maxwell, R. F., Jr., Baltimore, Md.
Mazer, W. M., Millburn, N.J.
Messenger, G. C., Trappe, Pa.
Meyer, J. H., New York, N.Y.
Michelson, M., Framingham, Mass.
Pietenpol, W. J., Murray Hill, N.J.
Sellars, E. A., Florence, S.C.
Silkman, H. G., Akron, Ohio
Wulfmeyer, J. A., Affton, Mo.

Admission to Senior Member

Bloembergen, N., Cambridge, Mass.
Brady, R. E., Inglewood, Calif.
D'Andrea, L. L., Wayne, Pa.
Goldsborough, P., Arlington, Va.
Isom, W. R., Haddonfield, N.J.
Jochem, N. L., Quincy, Ill.
Knapp, G. P., Waltham, Mass.
Mee, C. D., New York, N.Y.
Mikhail, S. L., Berkeley, Calif.
Miller, D. E., Van Nuys, Calif.
Milnes, A. G., Pittsburgh, Pa.
Namba, S., Chiyoda-ku, Tokyo, Japan
O'Loan, W. R., Hillsboro, N.H.
Page, O. D., Cleveland, Ohio
Pease, N. H., Granada Hills, Calif.
Peitzer, H. E., Elizabeth, N.J.
Petze, C. L., Jr., Wilmington, Del.
Poulos, P. S., Culver City, Calif.
Rippere, J. B., Wright-Patterson AFB, Ohio
Robb, A. S., Belleville, Ont., Canada
Rothrock, J. H., Wright-Patterson AFB, Ohio

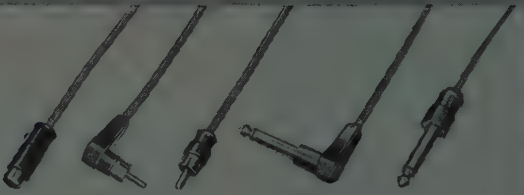
(Continued on page 100A)

Time Savers

SWITCHCRAFT® INC.

MOLDED CABLE ASSEMBLIES
(Audio Jumpers)

Different plugs molded directly to various cable combinations with innumerable terminations.



Custom-made to your requirements
COMPLETELY ELECTRICALLY SHIELDED

NEW
Miniature Phono Jack
3501-FP

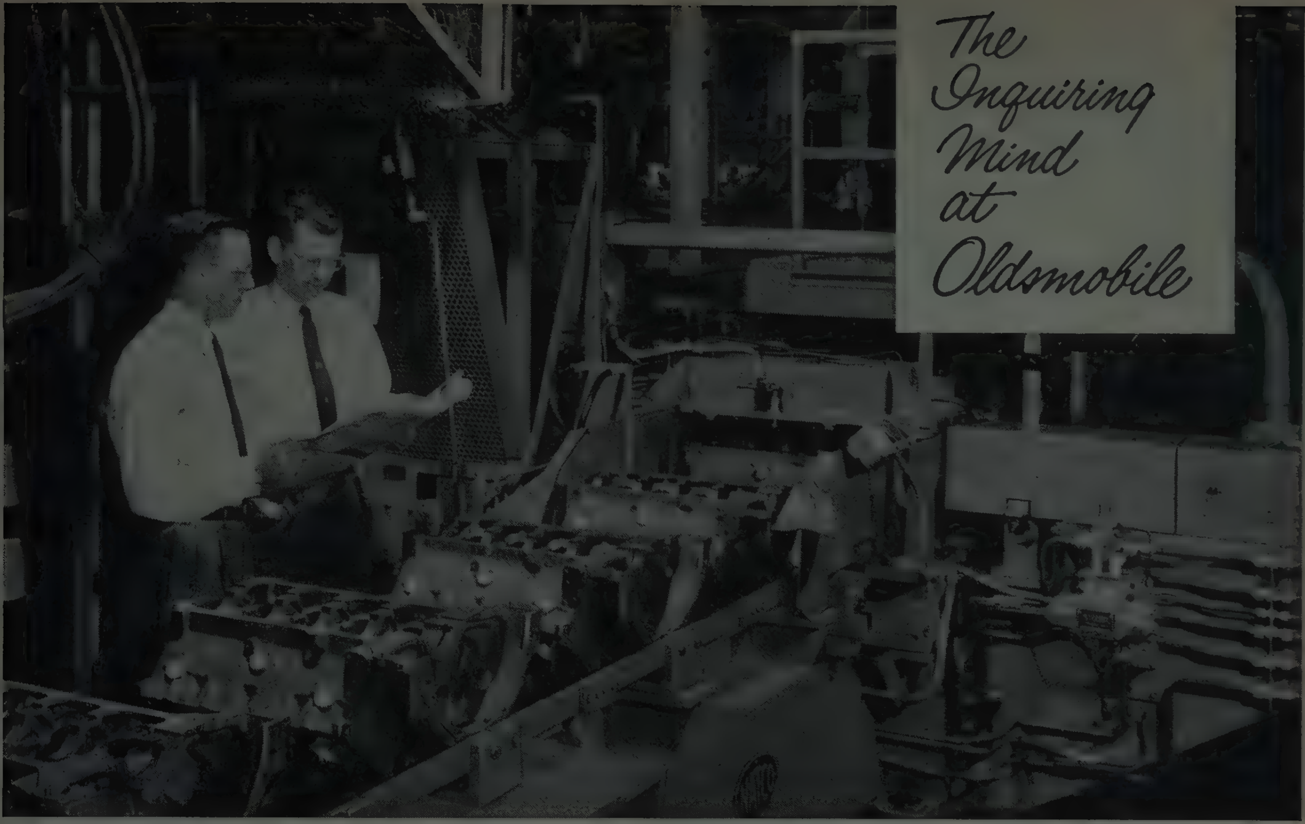
Eliminates front of panel mounting—requires only single hole. Can be mounted in multiples on ½" centers.

Straight Phone and Phono Plugs, Right Angle Phone and Phono Plugs and many others.
93 STOCK COMBINATIONS & LENGTHS—Shielded and Unshielded.
Send for NEW 1958 Catalog S-58 and Bulletin 191 on 3501-FP.

BOOTH 1343
1958 WESCON SHOW
Pan Pacific Auditorium—Los Angeles—Aug. 19-22.

SWITCHCRAFT® INC.
5545 N. Elston Ave.
Chicago 30, Ill.

Canadian Rep.: Atlas Radio Corp., Ltd., 50 Wingold Ave., Toronto, Canada.


The Inquiring Mind at Oldsmobile

no. 4 OF A SERIES

BEARINGS SO PERFECT YOU CAN "ROLL YOUR OWN"

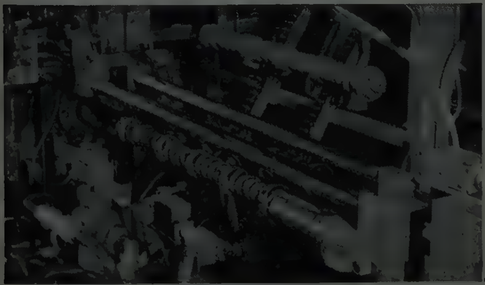
Automatic camshaft assembly machine assures bearing surfaces so perfect that every Oldsmobile camshaft can be turned by hand.

Installing a camshaft in an engine is like threading a needle. In the hand assembly of this critical part, the cam lobes often score the bearing surfaces. This results in high friction that will 'freeze' a camshaft so that it can be very difficult to turn manually. Olds engineers, however, have developed the only automatic camshaft assembly machine in existence. It installs camshafts so precisely that every one can easily be rotated by hand . . . a guarantee of unmarred cam lobes, less friction and *longer bearing life!*

To go one step further in eliminating any possibility of damaged cam lobes and journals, all handling is done entirely by mechanical means. After grinding, polishing and washing, camshafts are fed by conveyor to the installation machine and mechanically loaded. As the camshaft is properly installed and located in the engine block, a uniform protective coating of oil is applied for proper lubrication before the engine is ever started. So precise is this machine that cam bearings are never touched by the lobes or journals passing through even though clearances are as low as 0.0015 inches.

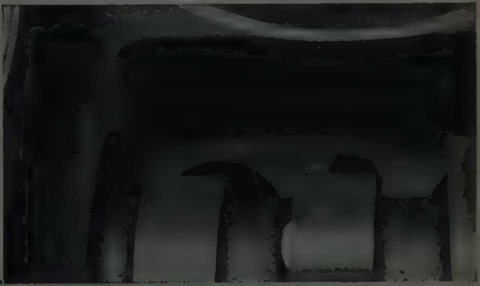
Attention to small, frequently hidden details is the true mark of quality craftsmanship. At Oldsmobile, quality is not "What will pass?", but rather, "Is this the *best* way to build automobiles?". It is this search for better ways to make better automobiles that makes Oldsmobile distinctive—a car in a class by itself. Discover the difference for yourself. Your friendly Oldsmobile Quality Dealer has a test drive reserved especially for you.

OLDSMOBILE DIVISION, GENERAL MOTORS CORP.



◀ Camshaft is rotated and lubricated as it automatically slides into engine block.

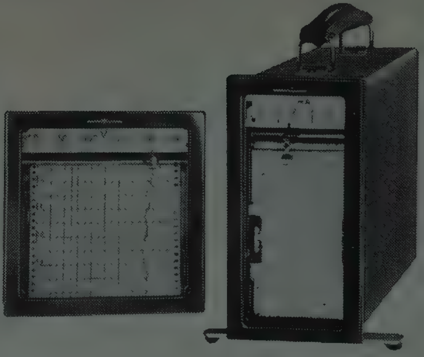
Scarred lobe on camshaft ▶ indicates scored bearing and may result in shorter camshaft and bearing life.



OLDSMOBILE

Pioneer in Progressive Engineering
...Famous for Quality Manufacturing

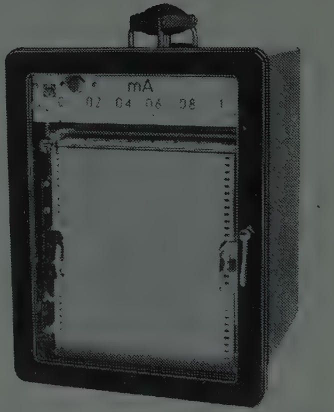
MINIATURE, STANDARD and DOUBLE SIZES!



MINIATURE RECORDERS

Square Model 85, in flush mount, weighs 16 lbs. and is 5⅝" square x 12¾" deep. Slim models 86 (portable) and 87 (flush) save half the width of standard recorders . . . measure 3¾" x 7⅛" x 8¾" and weigh only 9 lbs.

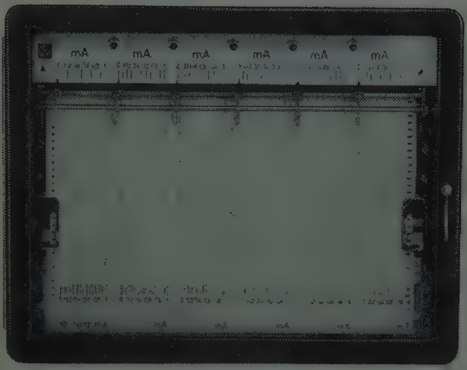
CURTISS-WRIGHT



STANDARD RECORDERS

Model 81 (portable) and 82 (flush) are also available for wall and projection mounting . . . take up to 3 channels. Weigh only 19 lbs. and measure 7½" x 9¹³⁄₁₆" x 7⅞".

PRECISION RECTILINEAR



DOUBLE SIZE RECORDERS

Models 83 (portable) and 84 (flush) take up to 6 channels. Wall and projection mounting available. Chart width is 9½". Measure 12¾" x 9¹³⁄₁₆" x 8¾" and weigh only 26 lbs.

STRIP CHART RECORDERS

Made under licensing agreements with one of Germany's leading instrument manufacturers . . . combine accuracy with ruggedness.

Important features: *Rectilinear Recording* with patented linkage that translates angular meter motion into proportional straight line • *Inkless and Ink Recording in One Unit* • *Three-Speed Transmission plus 60:1 Speed Change* from hours to minutes; provides six interchangeable speeds in all • *1% Accuracy* for moving coil movement • *Shock-proof movement . . . splash and dustproof steel cases.*

AC, DC, power and combination movements; wide choice of ranges and chart drives. Write for full information.

ELECTRONICS DIVISION
CURTISS-WRIGHT
CORPORATION • CARLSTADT, N. J.

Membership

(Continued from page 98A)

Shapiro, H. L., Massapequa, N.Y.
Shimbori, M., Chiyoda-ku, Tokyo, Japan
Shinkawa, H., Chiyoda-ku, Tokyo, Japan
Sichel, F. J. M., Burlington, Vt.
Spears, M. F., Westwood, Mass.
Sprague, G. F., Asheville, N.C.
Strip, J., Haddonfield, N.J.
Takeuchi, H., Chiyoda-ku, Tokyo, Japan
Trenaman, J. I., McLean, Va.
Underwood, O. J., St. Petersburg, Fla.
Watkins, G. F., Dayton, Ohio
Wells, C. A., Los Angeles, Calif.
Wittner, R. D., Massapequa, N.Y.
Wochinger, R., Huntington Station, L.I., N.Y.

Transfer to Member

Agins, B. R., Dayton, Ohio
Arbogast, J. L., Bellaire, Tex.
Arford, F. W., West Covina, Calif.
Arsenault, J. R., Arlington, Mass.
Auday, W. S., Norwalk, Calif.
Ausfresser, H. D., Baltimore, Md.
Backman, F. F., Poughkeepsie, N.Y.
Baer, E. W., III, Newport, R.I.
Bahr, W. B., Bloomington, Ind.
Baker, L. E., Houston, Tex.
Barabutes, T., Wewark, N.J.
Barash, S. A., New York, N.Y.
Bardonner, W. J., Jr., Fort Wayne, Ind.
Barry, D. T., Newport, R.I.
Behringer, N. C., Wantagh, L.I., N.Y.
Belcher, R. D., Thornwood, N.Y.
Bendel, S., Jr., Rochester, N.Y.
Benway, R. E., Marion, Ind.
Berch, W. H., Penfield, N.Y.
Bergeron, W. F., Paquannock, N.J.
Berlin, J., Brooklyn, N.Y.
Bertrem, C. J., Garden Grove, Calif.
Blanchette, C. F., Lawrence, Mass.
Blum, R. J., Dansville, N.Y.
Boisvert, C., Montreal, Que., Canada
Bonica, J. S., West Roxbury, Mass.
Bonney, L. A., Los Angeles, Calif.
Boyd, C. H., Flushing, L.I., N.Y.
Breakey, G. A., Trafford, Pa.
Brechenridge, A. G., Don Mills, Ont., Canada
Brock, F. M., Maddonfield, N.J.
Brumbaugh, G. M., Jr., New York, N.Y.
Bryerman, G. J., Jericho, L.I., N.Y.
Budlong, W. A., Whippany, N.J.
Bullard, R. L., Wappingers Falls, N.Y.
Burdick, D. D., W. Los Angeles, Calif.
Burke, A. M., Haddon Heights, N.J.
Burlingame, C. W., Sterling, Va.
Burrell, J. E., North Hollywood, Calif.
Butler, T. W., Jr., Ann Arbor
Carlson, E. S., Hawthorne, N.J.
Carroll, W. P., Whittier, Calif.
Casler, M. S., Evansville, Ind.
Chauvin, D. M., Glen Burnie, Md.
Christensen, W. V., Los Altos, Calif.
Cichanowicz, H. J., Linthicum Hts., Md.
Clark, A. R., Rolling Hills, Calif.
Clark, P. B., Syracuse, N.Y.
Clements, W. S., Sharon, Mass.
Cole, W. M., Jr., Rockville, Md.
Collins, W. G., New Hyde Park, L.I., N.Y.
Connelly, J. J., New York, N.Y.
Conover, W. V., Bethesda, Md.
Cordray, R. E., Chico, Calif.
Coughlan, G. B., Seattle, Wash.
Croft, W. S., Cedar Rapids, Iowa
Daggett, E. H., Murray Hill, N.J.
Dalle Mura, P. H., Baltimore, Md.
Davenport, K. R., San Jose, Calif.
Davies, R. W., Sunnyvale, Calif.
Davis, H., Los Angeles, Calif.
DeBoth, R. F., Broadview, Ill.
Dhem, R. E., Haddonfield, N.J.

(Continued on page 102A)

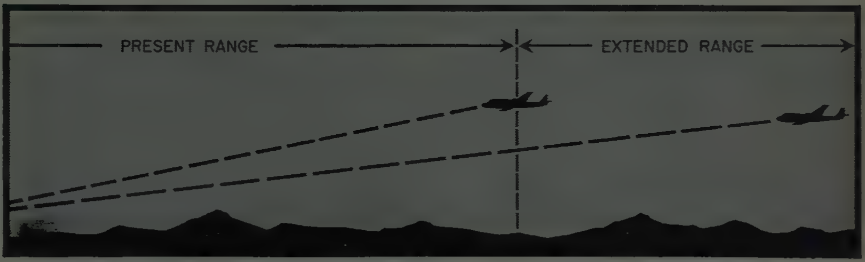
MICROWAVE AND SPECIAL TUBE NEWS from SYLVANIA

New Mixer Diodes can extend Radar Range by 18%

Premium 1N78B, 1N26A and 1N53B improve new and existing radar with unmatched ease and economy

Three new microwave diodes covering applications from 13,000 mc to 35,000 mc are now available from Sylvania. The new mixers, types 1N78B, 1N26A and 1N53B, have improved overall noise figures, more uniform RF impedance, and two of the types have greater resistance to burnout. They can extend radar coverage by as much as 18 percent*, provide more uniform performance from system to system, and increase operational reliability. An equivalent upgrading of equipment by any other means would demand a twofold increase in power.

The new crystals are exact retrofits of preceding types and are comparable in price. Each type is available in matched pairs to Sylvania's specification, which has recently been accepted as the industry standard by JETEC 14.7.



How radar range increases with Sylvania's new premium crystal diodes

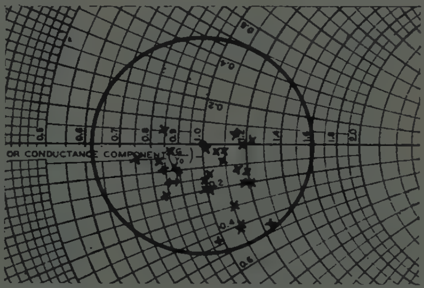
---

*2.8 db improvement in overall noise figure of 1N53B yields 18% increase in range.

Type 1N78B—Used in applications from 13,000 mc to 16,500 mc, the diode has an overall noise figure of 8.8 db, an improvement of 3 db over the 1N78 and 1 db over the 1N78A. It is being used extensively in doppler navigation equipment and in fire-control radar.

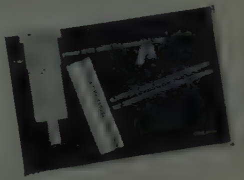
Type 1N26A—Designed for use as a mixer in superheterodyne radar receivers in the 24,000 mc region, the type is primarily used in airport traffic control equipment and in air-to-air missiles. Its 11.3 overall noise figure is a 1.8 db improvement over the 1N26. Its burnout resistance rating has been increased threefold to 0.3 erg.

Type 1N53B—This miniature coaxial type point contact silicon diode is designed for use as a mixer in the 35,000 mc region. Its major application is in Terrain Avoidance and Mapping Radar. The burnout resistance rating of the 1N53B is double that of the 1N53 and its overall noise figure has been reduced from 13.14 to 10.3. It is tested for a band width of 12 percent to assure good performance in any application in its frequency range. The new diode can also be used as a harmonic generator for very short wave-lengths.



VSWR measurement of a random selection of 1N78B's indicates the positive control over RF impedance of new Sylvania crystal mixers. The circle shows a VSWR of 1.6

New Edition—Complete up-to-date technical information on Sylvania's full line of Microwave Crystal Diodes is contained in a new revised edition of the 8-page booklet "Ratings and Characteristics of Microwave Crystal Diodes." Write Sylvania direct or call your Sylvania representative for a free copy of the new booklet.



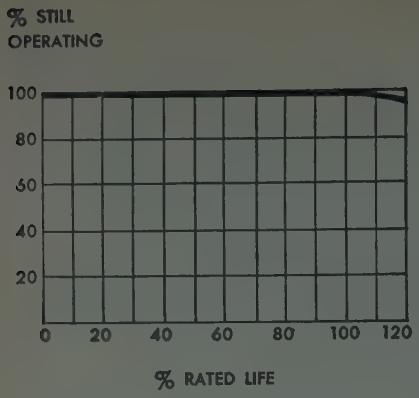
Electrical Characteristics & Ratings

	IN78B	IN26A	IN53B
Conversion Loss (db) max.	6.5	7.5	6.5
Output Noise Ratio max.	1.3	2.0	2.0
IF Impedance (Ohms)	365-565	300-600	400-800
RF Impedance (VSWR) max.	1.6	1.6	1.6
Burnout (erg)	0.3	0.3	32.8-37.0
Frequency (kmc)	16	24	0.3

SYLVANIA

Sylvania Electric Products Inc.
1740 Broadway, New York 19, N.Y.
In Canada: Sylvania Electric (Canada) Ltd.
Shell Tower Bldg., Montreal

LIGHTING • TELEVISION • RADIO • ELECTRONICS • PHOTOGRAPHY • ATOMIC ENERGY • CHEMISTRY-METALLURGY



If you want reliable transformers
..don't overlook this old solution

Right now, you demand more from transformers than ever before. You must have high reliability, even at extreme altitudes, and you need smaller lighter units.

Used, and *proved*, for decades, oil-encased transformers should not be forgotten in a search for new methods.

Everyone knows the advantages: effective convection of heat, excellent insulating properties, complete insurance against hidden leaks. Oil-*sealed* types (with a nitrogen bubble) are good, light, high-altitude transformers. Gas-free oil-*filled* types (with a bellows to allow for heat expansion) withstand very high voltage stresses. Except in the smallest sizes, they save space, too.

You can place several high voltage units close together in a single oil-filled case, and save case weight. Those connections moved inside the case no longer need large insulators. Even the units themselves can be smaller. This all adds up—particularly in high altitude service—to interesting savings in space and weight.

We make all sorts of transformers and special assemblies for the communication industry: encapsulated, cast in epoxy or foam, and just potted in pitch. But oil transformers still have an important place.

Whatever type you need, we'll be glad to hear from you. Our facilities in design, production, and quality control are at your service. Our experience, too.

CALEDONIA
ELECTRONICS AND TRANSFORMER CORPORATION
Dept. PI-8, Caledonia, N.Y.
In Canada: Hackbusch Electronics, Ltd.
23 Primrose Ave., Toronto 4, Ontario

Membership

(Continued from page 100A)

Demko, J. G., Lincroft, N.J.
Dere, G. B., Poona, India
Dickey, C. W., Philipsburg, Pa.
Di Franco, J. V., Flushing, L.I., N.Y.
Dinunno, J. J., Ednor, Md.
Dite, W., Los Angeles, Calif.
Dolan, B. A., St. Louis, Mo.
Dolan, F. J., Clifton, N.J.
Dolin, M., Hicksville, L.I., N.Y.
Dolle, W. C., New York, N.Y.
Dominy, J. F., Jr., Syosset, L.I., N.Y.
Donovan, R F., W. Lafayette, Ind.
Douglas, J. H., Bastrop, Tex.
Driscoll, J. F., Natick, Mass.
Dudley, D. J., Babylon, L.I., N.Y.
Dunn, C. J., Tuckahoe, N.Y.
Eisenhauer, F. E., New Hyde Park, L.I., N.Y.
Eisenmann, J. F., Norristown, Pa.
Englert, H. E., Huntington, L.I., N.Y.
Elkins, R., Salt Lake City, Utah
Emerson, R. R., Corona, Calif.
Erni, J. B., Boulder, Colo.
Falkowitz, M., Framingham, Mass.
Farkas, R. D., Valley Stream, L.I., N.Y.
Farlee, R. J., West Long Branch, N.J.
Favin, D. L., Whippany, N.J.
Fellhauer, H. E., Cedar Rapids, Iowa
Feltzin, A., Bayside, L.I., N.Y.
Fenton, M. J., Lincolnwood, Ill.
Fletcher, R., Jackson Heights, L.I., N.Y.
Feoranz, F. J., Rochelle Park, N.J.
Fidelman, D., Roslyn Heights, L.I., N.Y.
Fierstein, J. H., Philadelphia, Pa.
Figge, E. E., Levittown, L.I., N.Y.
Fleming, R. F., Jr., Charlottesville, Va.
Flint, R. B., Indianapolis, Ind.
Foley, T. J., Hatboro, Pa.
Fontana, J., Stanford, Calif.
Fox, E. I., Plainview, L.I., New York
Gager, C. H., West Islip, L.I., N.Y.
Galanter, M., Flushing, L.I., N.Y.
Gastineau, L., Pomona, Calif.
Gaylor, R., Phoenix, Ariz.
Geary, J. T., San Francisco, Calif.
Gills, L. C., Alexandria, Va.
Girodias, R. M., Garden City, L.I., N.Y.
Glazer, B. G., Collingswood, N.J.
Gneses, M. I., Farmingdale, L.I., N.Y.
Goldman, B. M., Cedar Rapids, Iowa
Gordon, H. L., Falls Church, Va.
Gottlieb, H. B., Freeport, L.I., N.Y.
Gracey, T. G., Toronto, Ont., Canada
Grassia, C. C., Littleton, Colo.
Gray, D. J., Cambridge, Mass.
Greenidge, G., Brooklyn, N.Y.
Guethlen, V. J., Concord, Mass.
Gustavus, H., Suitland, Md.
Halenbeck, A. D., Los Angeles, Calif.
Hall, G. D., Inglewood, Calif.
Halloran, V. P., San Francisco, Calif.
Harnack, W. P., Brooklyn, N.Y.
Harrold, G. B., Canandaigua, N.Y.
Hendler, A. J., Mineola, L.I., N.Y.
Henneberger, T. C., Jr., Essex Fells, N.J.
Hermida, R. J., West Islip, L.I., N.Y.
Hickman, W. C., Wantagh, L.I., N.Y
Hieken, C., Boston, Mass.
Hlavacek, A. R., Lowell, Mass.
Hockenjos, R. M., Mineola, L.I., N.Y.
Hutchinson, E. M., Hyattsville, Md.
Hutchison, T. C., Huntington, L.I., N.Y.
Imgram, R. H., Plainview, L.I., N.Y.
Immarco, A. E., East Elmhurst, L. I., N.Y.
Irish, F. E., Jr., Framingham, Mass.
Isherwood, H., Amityville, L.I., N.Y.
Jack, R. W., Pasadena, Calif.
Jacobsohn, D. H., Chicago, Ill.

(Continued on page 104A)

1/8"
T-30
1/4"
3/8"
5/8"
1-1/8"
QUALITY IS SOUND ECONOMY

American Beauty ELECTRIC SOLDERING IRONS GIVE YOU BOTH!

Each American Beauty Iron Model is carefully engineered for its specific use . . . built of the best materials available, to do your job better for longer.
Whether you select the tiny, new, ⅛" tipped Super-hot T-30's with plug-in transformers for production use on delicate connections or the full 1⅛" tipped "whoppers" for big area production work, you'll get the same quality —THE BEST.
Send us your soldering problems. Our many years of specialized experience are at your service.

Write for 16-page illustrated catalog containing full information on our complete line of soldering irons—including their use and care.

American Beauty
—A byword since 1894.

AMERICAN ELECTRICAL HEATER COMPANY
174-H DETROIT 2, MICHIGAN

NEW

LOW NOISE *
MINIATURE CHOPPERS
by AIRPAX

AIRPAX has developed a new series of miniature choppers characterized by extremely **low noise*** level for use in null seeking servo systems, instrument amplifiers, and similar applications.

Series 2300 choppers operate from a 6.3 VOLT 400 CPS source. Permanently adjusted contacts and AIRPAX armature design insure long life — over 5000 operational hours!

Drive coil leads are brought to top terminals minimizing drive and contact circuit coupling. Choppers are hermetically sealed for operation in any atmosphere.

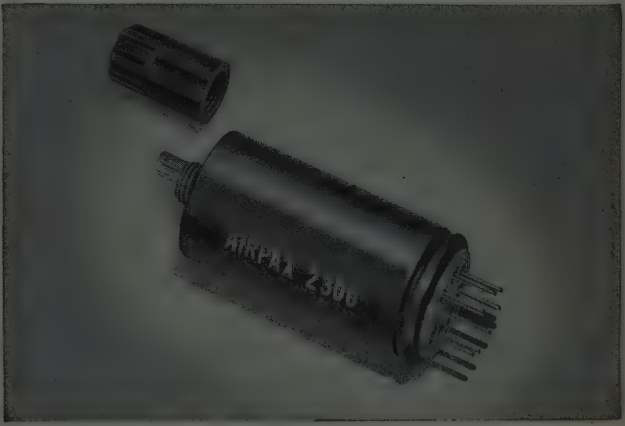
Although designed for dry or nearly dry circuits **surges of 2 milliamperes at 100 volts do not change operational characteristics!**

Normal operating temperature range is — 65C to + 100C. Extended temperature range choppers and variations of top terminal connectors and base headers, are also available from stock.

- ✓ Dependable
- ✓ Long Life
- ✓ Low Cost
- ✓ Available from stock

* Sub-micro-volt region

ACTUAL SIZE



SERIES 2300 FOR 400 CPS

AIRPAX

THE AIRPAX PRODUCTS COMPANY CAMBRIDGE DIVISION, CAMBRIDGE, MD.

MARCONI INSTRUMENTS

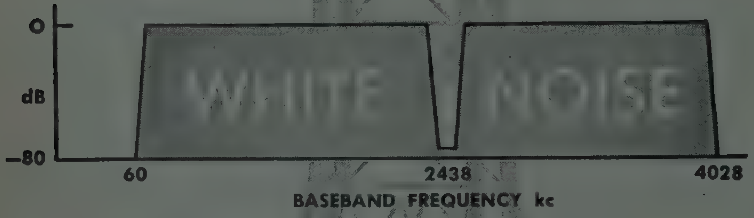
Linearize

Microwave Installations...

. . . and cover Baseband, IF and Carrier Frequencies of the most sophisticated multi-channel systems engineers are now designing. These entirely new instruments are now in production; they meet C.C.I.R. specs. and are flexible to customers' specific needs. Examples:

WHITE NOISE TEST SET Model 1249

Measures intermodulation distortion in systems handling up to 960 channels. Comprises Noise Generator, Receiver and modular Filter Assembly which facilitates changing filters to suit different systems. Diagram indicates test on 960 channel installation.



DERIVATIVE TEST SET
Model 1259

A Sweep Generator and self-calibrating CRT display are provided to measure modulator/demodulator linearity. The first derivative, or slope, of the modulator response is automatically plotted against instantaneous I.F.: discrimination is 0.1 db.

CARRIER TEST SET
Model 1248

Includes a Signal Generator with CW, frequency sweep and AM output, a Receiver with square law detector and markers for response measurement, and a Noise Generator with output up to 15 dbm. Equipment already available in 1700-2300Mc band; other bands under development.

We invite your inquiries on this unique specialized equipment.

MARCONI instruments
111 Cedar Lane • Englewood, New Jersey
LOwell 7-0607

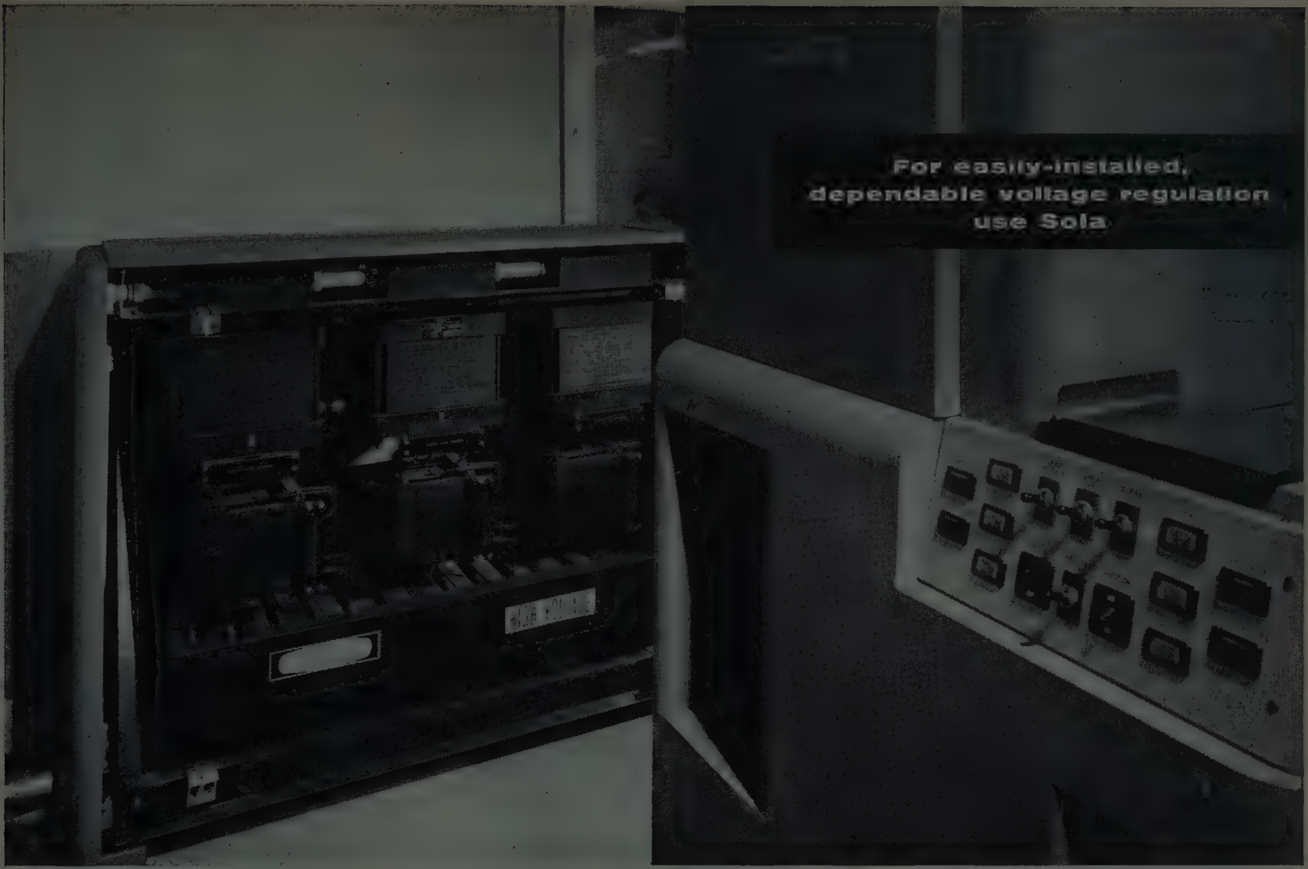
WESCON SHOW BOOTH 1654

Membership

(Continued from page 102A)

Jackson, W. E., Winchester, Mass.
James, B. O., Bristol, Tenn.
Jernakoff, G., Loudonville, N.Y.
Johnson, A. B., Chestnut Hill, Mass.
Johnson, G. L., East Syracuse, N.Y.
Johnson, H. A., Norwood, Mass.
Johnson, O. E., Oaklyn, N.J.
Johnston, H., Roslyn Heights, L.I., N.Y.
Jouvenat, J. M., San Francisco, Calif.
Kabrisky, M. J., Rome, N.Y.
Kahler, R. C., Weston, Mass.
Karg, L. A., South Norwalk, Conn.
Karpen, E. W., Mineola, L.I., N.Y.
Kascha, G. E., Ludlowville, N.Y.
Kassler, R., Jackson Heights, L.I., N.Y.
Katz, S., Brooklyn, N.Y.
Kaufman, A. L., Stamford, Conn.
Kay, R. H., Rochester, N.Y.
Kelly, J. F., Scranton, Pa.
King, C. J., Albuquerque, N.M.
Koenig, R. H., Cambria Heights, L.I., N.Y.
Kohlmann, H. P., Fairborn, Ohio
Kokidko, A., Framingham, Mass.
Kopeloff, B. G., Framingham, Mass.
Kozicki, H., Jackson Heights, L.I., N.Y.
Lee, A. E., Liverpool, N.Y.
Leitch, J. G., Edmonton, Alta., Canada
Litwin, S., Dayton, Ohio
Low, F., New York, N.Y.
Luke, J. W., New York, N.Y.
Marafiot, J. J., Corning, N.Y.
Milton, R. T., Schenectady, N.Y.
May, J. C., Ithaca, N.Y.
McCarthy, E. A., Eau Gallie, Fla.
McKechnie, R. M., Inglewood, Calif.
McKinley, W. D., Wellesley, Mass.
Mengle, L. I., Lancaster, Pa.
Meyer, D. E., Jr., Denver, Colo.
Mikaelian, M., Syracuse, N.Y.
Momberger, P. E., Ilion, N.Y.
Montague, L. L., Tewksbury, Mass.
Monturo, J. B., Long Island City, L.I., N.Y.
Moxley, S. D., Jr., Cincinnati, Ohio
Mullin, J. F., Queens, L.I., N.Y.
Murakami, P. K., Utica, N.Y.
Musacchio, A. A., Brooklyn, N.Y.
Nakasata, J., Cambridge, Mass.
Nehrbas, T. C., Huntington, L.I., N.Y.
Nelson, R. A., Bridgeport, Conn.
Nicholson, J. F., Horseheads, N.Y.
Nickerson, P. E., Baltimore, Md.
Odden, R. B., Buffalo, N.Y.
Oliver, O., Jr., Seaford, L.I., N.Y.
Olson, C. W., Huntington Station, L.I., N.Y.
O'Neill, J. F., Springfield, Pa.
Osgood, R. C., Quincy, Mass.
Oswald, H., Yonkers, N.Y.,
Oxley, V. C., Kenmore, N.Y.
Pace, F. P., Syosset, N.Y.
Patton, P. C., Lawrence, Kan.
Payne, R. S., Seattle, Wash.
Pulver, M., Buenos Aires, Argentina
Ramella, P. R., West Allenhurst, N.J.
Randall, N. C., Philadelphia, Pa.
Ratkevich, A. E., San Diego, Calif.
Reddicks, J. E., Redondo Beach, Calif.
Rogers, G. J., Falls Church, Va.
Rosenberg, D., Brooklyn, N.Y.
Rothschild, R. S., New York, N.Y.
Sarrafian, G. P., Dallas, Tex.
Schapiro, R., Pomona, Calif.
Schiess, G., Watertown, Mass.
Senise, J. T., Menlo Park, Calif.
Seshu, S., Syracuse, N.Y.
Severance, F. D., High Point, N.C.
Silverman, J. B., Roslyn, Pa.
Sines, W. U., Jr., Pittsburgh, Pa.
Sinnette, J. T., Jr., Altadena, Calif.
Slobodzinski, E. J., Hopewell Junction, N.Y.

(Continued on page 106A)



FIVE constant voltage transformer types answer most stabilizing needs

1 **The Harmonic-Free Constant Voltage Transformer** gives you all the advantages of static-magnetic voltage regulation *plus* "sine-wave" output. Remington-Rand, for example, uses this 9 kva transformer to provide continuous, completely-automatic voltage regulation to their Univac model 60 and 120 computers. The Sola regulator is shown above at the left with the front panel of the cabinet removed. It is a custom-built unit.

Sola harmonic-free regulators deliver ±1% regulation with ±15% line voltage variation. The output wave has less than 3% total rms harmonics. Available from stock in seven sizes ranging from 60 va to 3kva; custom designs manufactured to your specifications in production quantities.

2 **Standard***: Constant Voltage Transformers for electrical and electronic equipment . . . regulation ±1% . . . response within 1.5 cycles . . . no tubes, moving parts or manual adjustments . . . static-magnetic regulation ... limits current on load faults.

3 **Plate-Filament***: Regulation is ±3% with line input between 100-130v . . . plate and filament windings are combined on a single, compact core for chassis mounting . . . good isolation of input and output circuits . . . automatic, static-magnetic regulation.

4 **Filament***: Regulation ±1% with input voltage fluctuations up to ±15% . . . 6.3v output for large numbers of electron tubes . . . current-limiting action minimizes cold inrush currents, also protects against damage from load faults ... 75-80% efficiency.

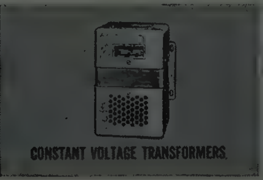
5 **Adjustable, Harmonic-Free:** Provides output adjustable from 0-130 volts ac, also fixed 115 volts ac . . . regulates within ±1% with less than 3% total rms harmonic content . . . portable for lab or shop bench use, or mounts on 19" relay rack.

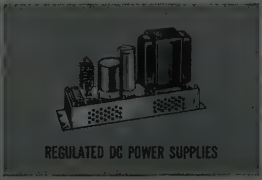
*Available from stock or custom-designed.

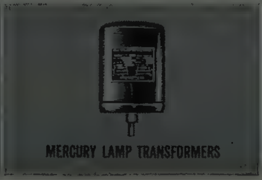
For complete data write for Bulletin 1H-CV-170

Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill., Bishop 2-1414 • Offices in Principal cities • In Canada, Sola Electric (Canada) Ltd., 24 Canmotor Ave., Toronto 14, Ont.

SOLA


CONSTANT VOLTAGE TRANSFORMERS


REGULATED DC POWER SUPPLIES


MERCURY LAMP TRANSFORMERS

FLUORESCENT LAMP BALLASTS

60 d b ANTENNA PATTERNS

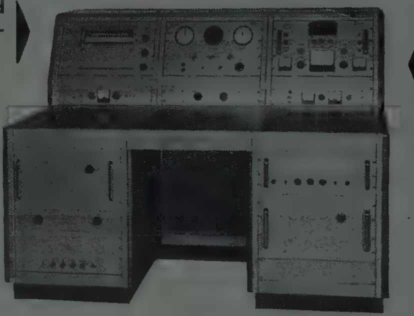
with sensitivities up to —95dbm

Control Unit for Antenna Positioner or Model Tower.

Model 121B3 Rectangular Recorder has linear, logarithmic and square root pen responses.

Model 122B Polar Recorder may be installed here.

Model 301R Signal Source Remote Tuning Unit.



Model 402C Wide Range Receiving System covers from 30 mc to greater than 75 mc without plug-in units. Antenna may be located up to 75 feet away.

The standard S-A Logarithmic Antenna Pattern Recorders plot a graph linear in db over a 40 db range. The extended range of the new system is obtained by a feedback network between receiver and recorder.

SEE THIS UNIT IN BOOTH 1437 AT THE WESCON SHOW

Write for latest catalog and booklet on Antenna Pattern Measurements Techniques.

SCIENTIFIC-ATLANTA, INC.

2162 Piedmont Road, N. E.
Atlanta 9, Georgia

SPOT GALVANOMETER

Type **GVM 22**

7 CURRENT RANGES:
5 to 500 μA full scale
0.8 to 6 mV voltage drop

7 VOLTAGE RANGES:
1 to 100 mV full scale
200 ohms/mV

QUICK & APERIODIC RESPONSE

Line of 5 galvanometers supplied for different applications. • Light and handy instrument. • Power line or battery operation.

RADIOMETER

72 Emdrupvej, Copenhagen NV, Denmark

Represented in Canada by
BACH-SIMPSON
London/Ontario
Represented in the United States by
WELWYN INT. INC.
3355 Edgecliff Terrace, Cleveland 11 Ohio

Membership

(Continued from page 104A)

Smith, C. C., Milwaukee, Wis.
Smith, D. M., New York, N.Y.
Smith, P. E., Sierra Madre, Calif.
Soscia, B. L., Cranston, R.I.
Spongberg, R. C., Reading, Mass.
Stevens, E. F., South Boston, Mass.
Teacher, C. F., Philadelphia, Pa.
Tudor, J. R., Columbia, Mo.
Underwood, R. W., Alexandria, Va.
Wargo, J. J., Cambridge, Mass.
Wetmore, G. B., Silver Spring, Md.
Whalen, R. J., Kingston, N.Y.
Whitby, L. S., Philadelphia, Pa.
Willey, J. R., Pennsauken, N.J.
Wills, R. H., Kenmore, N.Y.
Winkler, V. D., Poughkeepsie, N.Y.
Williams, W. E., Lake Jackson, Tex.
Wolf, G. T., Auburn, N.Y.
Wolff, E. A., Richardson, Tex.
Wolkstein, H. J., Newark, N.J.
Woodburn, E. S., Jr., Methuen, Mass.
Woodside, W. J., Phoenix, Ariz.
Zellmer, W. G., China Lake, Calif.

Admission to Member

Allan, R. E., Dallas, Tex.
Bell, K. R., Chicago, Ill.
Berglund, J. F., Dallas, Tex.
Berman, A. D., New York, N.Y.
Betts, D. C., Seattle, Wash.
Bletzinger, P., Yellow Springs, Ohio
Boone, J. V., Dayton, Ohio
Botwinick, E., New Rochelle, N.Y.
Brath, P. W., Wilmerding, Pa.
Breesman, R. N., Dayton, Ohio
Brown, H. M., Battle Creek, Mich.
Brown, J. L., University Park, Pa.
Brudner, H. J., New York, N.Y.
Budak, A., Ft. Collins, Colo.
Burkey, E. L., Lodi, N.J.
Cannoy, M. K., Cedar Rapids, Iowa
Carmody, L. M., Arlington Heights, Ill.
Carrick, R. L., Arlington, Va.
Crabtree, W. A., Dallas, Tex.
Crank, J. B., Dallas, Tex.
Combellick, J. D., Cedar Rapids, Iowa
Conover, J. C., Wright Patterson AFB, Ohio
Corrigan, J. P., Flushing, L.I., N.Y.
Deschamps, J. D., Saint-Cloud, Seine-et-Oise, France
Doty, A., Wright-Patterson AFB, Ohio
Dubin, D., Rochester, N.Y.
Du Teil, R. Z., Silver Spring, Md.
Elliott, H. A., Palo Alto, Calif.
Errante, E. P., Bogota, Colombia, S.A.
Erteza, A., Peoria, Ill.
Fehr, D. L., Rome, N.Y.
Fine, E. M., Yonkers, N.Y.
Fiocco, G. D., Chelmsford, Essex, England
Foster, H. B., Haddonfield, N.J.
Gann, G. D., London E. C. 3, England
Gegon, P. H., Arlington, Tex.
Geleruter, A., Lodi, N.J.
Giarola, A. J., Seattle, Wash.
Glover, E. B., Melbourne Beach, Fla.
Golding, E. I., Annapolis, Md.
Goldman, A., Philadelphia, Pa.
Gooderham, D., Ottawa, Ont., Canada
Gouin, W. P., Ottawa, Ont., Canada
Gram, H. B., Jr., Belmont, Mass.
Griffin, J. P., New York, N.Y.
Guy, L. S., Orlando, Fla.
Haijsman, L. C., Battle Creek, Mich.
Haill, H. K., Houston, Tex.
Hammerslag, J. G., San Pedro, Calif.
Hanotte, P. E., Maywood, Ill.
Harjess, R. E., Hyattsville, Md.
Harper, P. T., Los Altos, Calif.
Harris, H. E., New York, N.Y.

(Continued on page 108A)

ONLY
± SIX MICROVOLT
INPUT DRIFT OVER
AN EIGHT HOUR
PERIOD
SIZE:
2-15/16" x 6-15/16" x 10"

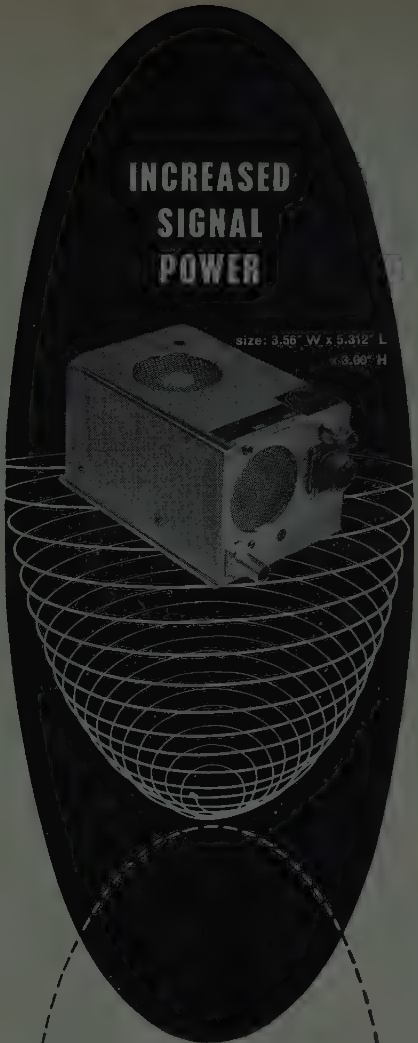
high input impedance with extremely low drift

The Model REL-120 is a completely transistorized, direct-coupled, instrumentation d-c amplifier featuring: (1) long life resulting from the use of such passive elements as transistors and diodes; (2) low heat generation from an average required input power of only 10 watts; and (3) a self-contained power supply that works directly from either 60 or 400 cycles.

For full specs, write for Data File IRE-501-1

RHEEM MANUFACTURING COMPANY
ELECTRONICS DIVISION
7777 Industry Avenue, Rivera, Calif.
phone: RAymond 3-8971

Rheem



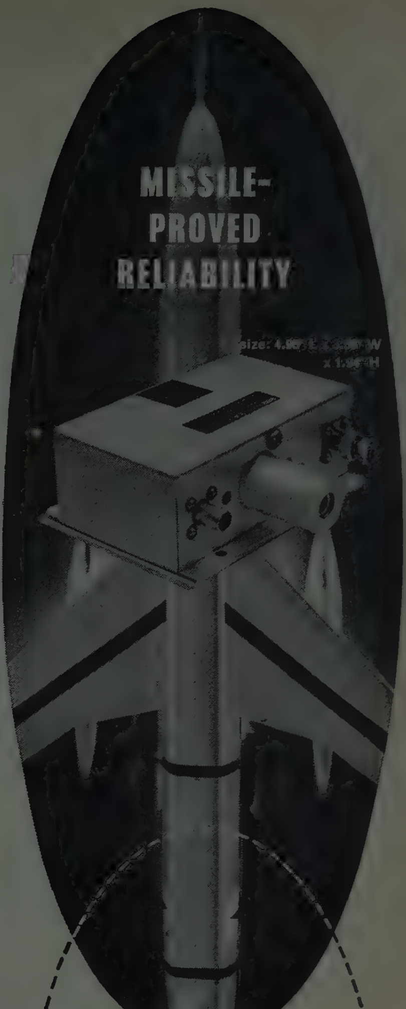
in the 215 mc to 260 mc telemetering band

The Model REL-10 R-F Power Amplifier is a high-output unit for airborne applications. With power outputs from 10 to 100 watts, it dramatically increases the range of missile and aircraft telemetering systems...teams up with presently available FM transmitters...meets missile environmental requirements.

For full specs, write for Data File IRE-500-1

RHEEM MANUFACTURING COMPANY
ELECTRONICS DIVISION
7777 Industry Avenue, Rivera, Calif.
phone: RAymond 3-8971

Rheem



in the 235 mc to 245 mc telemetering band

The Model REL-09-HF is a ruggedized miniature R-F power amplifier. With a solid history of reliability in current missile systems, the unit has proved capable of withstanding the most rigorous airborne applications. The 5-inch, 1-pound amplifier delivers an 8-watt output to a 52-ohm load with a 1.4-watt input drive.

For full specs, write for Data File IRE-504-1

RHEEM MANUFACTURING COMPANY
ELECTRONICS DIVISION
7777 Industry Avenue, Rivera, Calif
phone: RAymond 3-8971

Rheem

Speaking Frankly to

ENGINEERS:

Bendix
KANSAS CITY

LONG RANGE
PRIME
CONTRACTOR
FOR THE A.E.C.

You, like other electronic engineers, are frequently a target for high-pressure recruiting techniques. So you may justifiably wonder how we've successfully managed to obtain professional people without resorting to supersalesmanship. Our secret, if we have one at all, is that we simply relate the facts of life at Bendix, Kansas City; it so happens that these are potent facts.

New developments in our continuing expansion program now prompt us to present once more a few of these facts and to welcome your inquiry.

We may surely point to a realistic salary structure but this is not the principal reason why we attract and retain outstanding people. A far more likely reason is that we are basically an engineering corporation. Because most of our top executives are engineers themselves they understand and appreciate technical problems, a fortunate situation which naturally induces an atmosphere most stimulating to creativity, harmony and professional progress.

Being a prime contractor for the Atomic Energy Commission, we can't reveal the exact nature of our work. We can tell you, however, that we're engaged in a long-term program involving the design, development and manufacture of extremely precise, complex electronic and electro-mechanical devices.

Now—in the fields of electronic, electrical and mechanical engineering—we offer responsible positions to men with a degree and at last a 5-year demonstrated record of substantial professional accomplishment. These men, after indoctrination in our techniques, should be capable of working rapidly into design engineering, project engineering or supervisory responsibilities.

Design experience in *miniaturized airborne electronic* equipment is particularly desirable for many of the openings.

If you're a *radar engineer* with a background in microwave techniques (including photo-etched microwave circuitry), you'll be interested in our unique precision production equipment.

Experience in *servo, video* and *IF amplifiers* may qualify you for opportunities in production test equipment design and automation.

Perhaps you have had design and production experience with *plastic encapsulation techniques* and the general application of fabricated and molded plastics. Then we'd like to tell you about our openings in this field and of our molding and laminating facilities.

We purchase a wide variety of *special* vacuum tubes designed for our specific requirements. Your experience in *vacuum tube application* may qualify you for the critical project group which is responsible for coordinating such development and production.

If you're a qualified *electronic components engineer* you'll find real challenge in either our electronic components engineering section or our electronics production design department. Here exceptionally stringent reliability standards continually push the state of the art in several areas and, in a responsible position, you'll enjoy this truly sophisticated work in reliability engineering.

P.S. You and your family will surely like Kansas City. It's a really pleasant, clean, beautiful, notably-progressive city, featuring low-cost living, a favorable climate and plenty of cultural, educational and recreational facilities. Our plant is a few minutes' drive from choice new residential suburbs which offer numerous, new highly-rated public schools. If you're interested in earning an advanced degree at nearby universities we offer a helpful program. Bendix pays relocation expenses, of course.

Mr. J. L. Breslin, Professional Personnel
Bendix Aviation Corporation
Box 303-AB, Kansas City, Mo.

I'd like to talk to you about the position
....
I understand you'll treat this inquiry in strict confidence.
Name ....
Street .... Phone ....
City .... State ....

ENGINEERS • ENGINEERS • ENGINEERS • ENGINEERS • ENGINEERS • ENGINEERS • ENGINEERS •

• ENGINEERS • ENGINEERS •

Membership

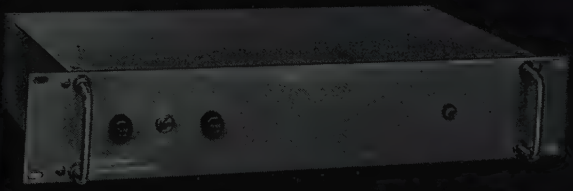
(Continued from page 106A)

Heidebrecht, L. E., Newmarket, Ont., Canada
Hennessey, F. L., Washington, D.C.
Hibbett, R. M., Newark, N.J.
Hill, P. D., Las Cruces, N.M.
Hines, N. M., New York, N.Y.
Hingston, A. J., Reading, Mass.
Hitzeroth, E., J., Windsor, Ont., Canada
Hodges, A. J., Dallas, Tex.
Holland-Martin, C. G., London W 1., England
Hollis, W. T., III, West Newton, Mass.
Hong, K. G., San Francisco, Calif.
Honigman, R. L., Syracuse, N.Y.
Houser, H. R., Silver Spring, Md.
Huopana, R. O., Owego, N.Y.
Jacks, H. G., Seattle, Wash.
Jacobson, E. H., Mobile, Ala.
Jennings, R. L., Lodi, N.Y.
Johanningsmeier, W. F., Kingston, N.Y.
Johnson, D. M., Greenville, Tex.
Johnson, V. H., North Highlands, Calif.
Jones, B. H., Oklahoma City, Okla.
Jones, I. J., Kansas City, Mo.
Krammer, D. E., Cincinnati, Ohio
Karmen, A., St. Petersburg, Fla.
Karmin, I., New York, N.Y.
Karpinski, A. L., Baltimore, Md.
Keeler, J. S., Waterloo, Ont., Canada
Kim, K., Seoul, Korea
Kinner, H. R., Cambridge, Mass.
Klein, W., Dayton, Ohio
Knights, G. F., Edmonton, Alta, Canada
Kozin, C. H., West Lafayette, Ind.
Kraguljac, N., Detroit, Mich.
Kramer, S., Hicksville, L.I., N.Y.
Kulka, E. R., Mt. Vernon, N.Y.
Kyropoulos, L., Bayside, L.I., N.Y.
Lackey, H. B., Charleston, S.C.,
Langley, L. W., Houston, Tex.
Lascaris, C. A., Athens, (K), Greece
Laughlin, J. G., Jr., Santa Ana, Calif.
Lauman, E. O., District Heights, Md.
Leeson, F. D., Toronto, Ont., Canada
Leitner, P. R., Littleton, Colo.
Lewis, W. I., Butler, Pa.
Lockwood, V. M., Tucson, Ariz.
Lontka, R. E., East Orange, N.J.
Luce, E. S., Houston, Tex.
Luff, F. T., Wheaton, Md.
Lum, M. A., Garden Grove, Calif.
MacDonald, J. N., Thornwood, N.Y.
Marrone, P. C., Fair Lawn, N.J.
Marshall, C. H., Dallas, Tex.
McDuffie, T. E., Hollis, L.I., N.Y.
McIlroy, C. J., Ville St. Michel, Que., Canada
McIntosh, V. C., Dayton, Ohio
McLauchlan, D. J. A., Bristol, England
McMillin, K. M., Houghton, Mich.
Meisel, H. R., Irvington, N.J.
Meulemans, J. I., Dayton, Ohio.
Mithal, G. K., Jabalpur, India
Mondress, M., Levittown, Pa.
Morris, J. T., Dayton, Ohio
Morrison, J. A., Jr., Dallas, Tex.
Mott-Smith, J. C., Boston, Mass.
Mulholland, K. H., St. Paul, Minn.
Myint, A., Rangoon, Burma
Nacke, C. C., Jr., Haddonfield, N.J.
Notestine, D. D., Dayton, Ohio
Oberg, M. F., Mission, Kan.
O'Donnell, C. F., New Orleans, La.
Osinger, A. R., Houston, Tex.
Ozarowski, A. J., Garfield, N.J.
Pardovich, J. T., Ramsey, N.J.
Parry, H. J., North Hollywood, Calif.
Patterson, R. A., Staten Island, N.Y.
Peratino, G. S., Springfield, Va.
Perchyshyn, E., Minneapolis, Minn.
Peters, N. S., Kansas City, Mo.
Peterson, D. A., Newark, N.J.
Phipps, A. R., Rochester, N.Y.

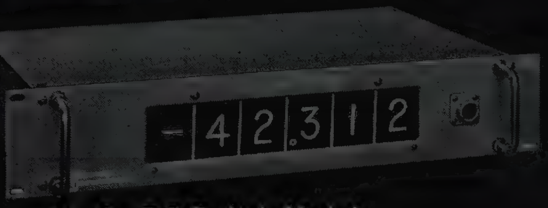
(Continued on page 110A)

Precision instruments for automatically measuring DC, AC-DC, Ohms and DC-AC ratios constructed from basic modules.

For example:

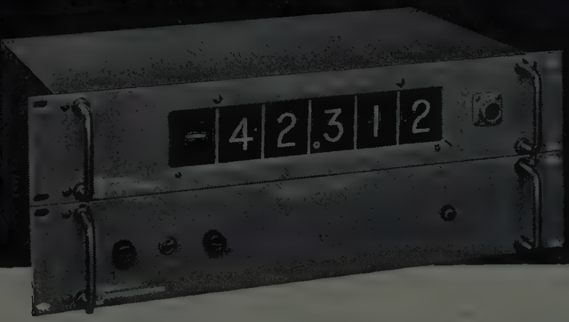


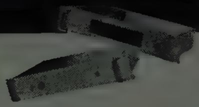
Combine the Universal Power Module



with the DC Switch Module

to get an 0.01% Digital Voltmeter





a completely new idea in digital instrumentation!

Now from five basic E-I modules, almost any combination of instruments can be assembled for precision, digital measurement of DC, AC-DC, Ohms and AC-DC Ratios. The basic E-I modules never become obsolete. As needs change, simply regroup or add new modules. This new modular concept provides maximum versatility and enables equipment to be kept current at minimum cost and engineering.

New engineering specification and other features have been incorporated into the basic modules from the experience of over 2,500 digital instruments in the field. Where applicable, all circuits have been fully transistorized to provide increased reliability, low power consumption, low heat dissipation and to eliminate radio noise and line transients.

New catalog sheets *give the complete story of this newest advance in digital instrumentation and complete specifications on all modules. Write for your set today.*

ELECTRO INSTRUMENTS INC. 3794 Rosecrans, San Diego, California

NEW, LOW FREQUENCY RELIABILITY IN GLASS-ENCLOSED CRYSTAL

Precision components of the new RHG-DP crystals are enclosed and hermetically sealed in glass holders to assure maximum internal cleanliness and most reliable evacuation. The result is a series of sturdy, miniature, low frequency units having excellent long-term stability and higher Q.

TYPICAL VALUES FOR 2 KC UNIT*

Frequency range	1 to 15 kc
Holder	T5 1/2 glass bulb —Noval Base
Temperature range	−55 to +100°C
Frequency tolerance	±.015%
Effective resistance	75,000 ohms max.
Aging 8 hours—100°C	±.001% max.
Meets MIL specifications for vibration stability	

*Reeves-Hoffman manufactures a broad line of crystals in the range from 1 to 1000 kc.

REEVES-HOFFMAN

WRITE FOR BULLETIN RHG-DP

DIVISION OF
DYNAMICS CORPORATION OF AMERICA
CARLISLE, PENNSYLVANIA

VECO THERMISTORS, VARISTORS RATED HIGHEST QUALITY BY INDEPENDENT LABORATORIES

What's behind this quality? — it's VECO's ever-constant research, development and engineering program, designed to keep abreast of today's fast-changing industry. Backed by one of the country's largest and finest equipped plants, VECO works hand-in-hand with customers to improve existing products and develop new applications utilizing Thermistors and Varistors.

VECO also publishes technical and educational literature to tell customers of the uses and characteristics of Thermistors and Varistors. A new Technical Catalog, covering over 250 VECO stock items, and an educational series entitled "Meet The VECO Thermistor" are available. Write or call for your free copy today!

Also Manufacturers of **VECO**

- Gas Analysis and Chromatography Cells
- Combustion Analyzers
- Temperature-Sensing Devices
- Low Temperature (Lox Probes) (Pat. Applied For)
- Tap-A-Therm (Multi-Tapped Thermistors) (Pat. Applied For)
- Custom-Built, Constant Temperature Baths and Controls
- Compactrol (Electronic Controls) (Pat. Applied For)

Descriptive literature covering each item available on request

VECO Trade mark Victory ENGINEERING CORPORATION
114 Springfield Road, Union, N. J.
Telephone MUrdock 8-7150

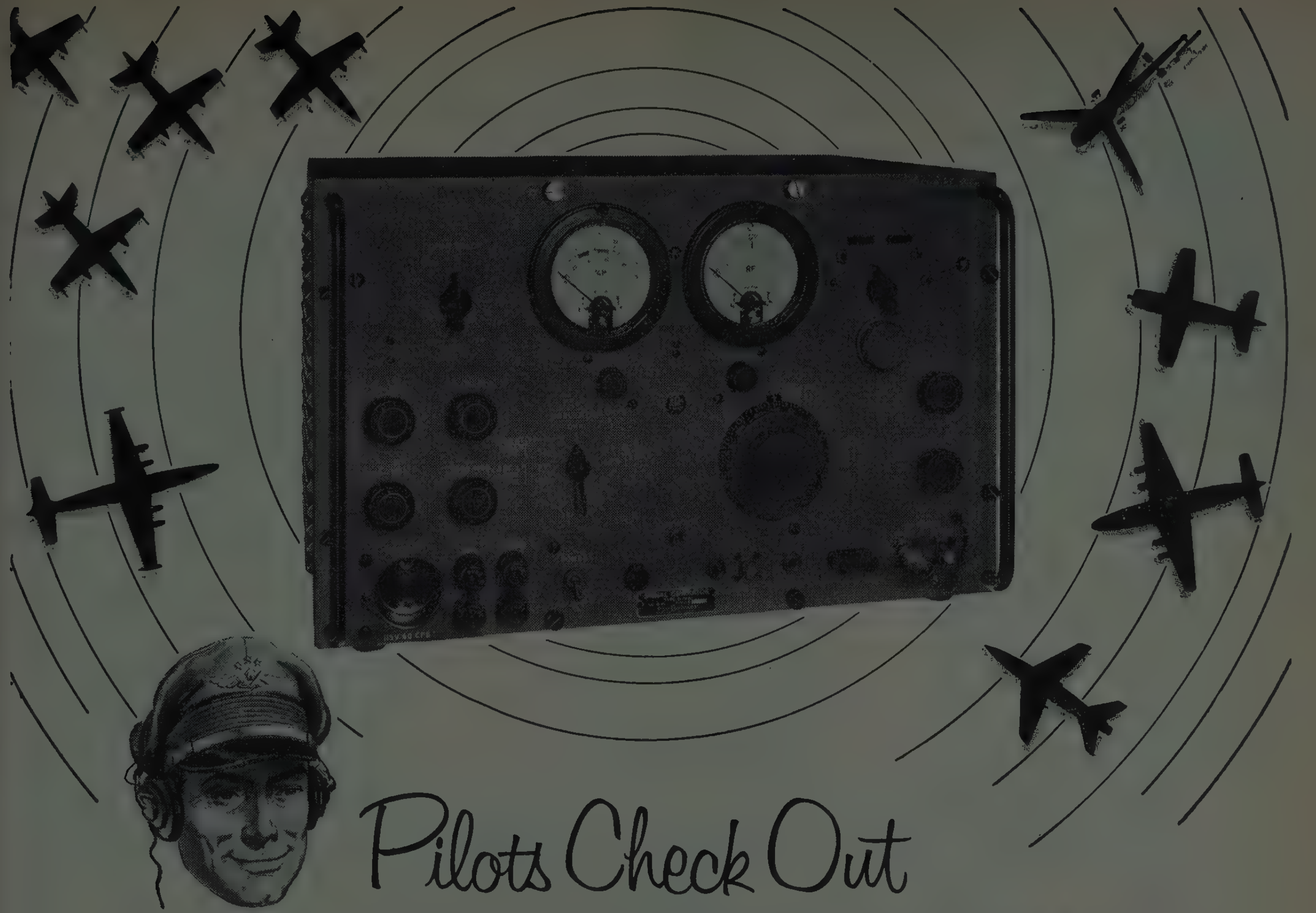
See us at the 1958 WESCON Show, Booth 1734—August 19-22, Pan Pacific Auditorium, Los Angeles, California.

Membership

(Continued from page 108A)

Pitts, J. E., Jr., Redwood City, Calif.
Potts, D. L., Los Angeles, Calif.
Pratt, S. L., Riverside, Calif.
Prechtel, C. J., Cleveland, Ohio
Qadri, M. S., Lahore, Pakistan
Raju, P. V., Andhrapradesh, South India
Ree, J., Philadelphia, Pa.
Reich, R. F., Los Angeles, Calif.
Rietmeyer, H. W. F., Staten Island, N.Y.
Rippin, D. W., Ware, Herts, England
Rohrer, F. D., Anchorage, Alaska
Root, W. E., Chester, Pa.
Ross, I. L., Philadelphia, Pa.
Rowlinson, D. E., St. Petersburg, Fla.
Russell, B. J., Chicago, Ill.
Saran, G. S., Seattle, Wash.
Saunders, J., Philadelphia, Pa.
Savoy, R. P., Dayton, Ohio
Schaffer, E., New York, N.Y.
Schandl, E., Lynwood, Calif.
Schneider, F. H., Alexandria, Va.
Schon, F. K. K., Montreal, Que., Canada
Seike, H. K. A., Toledo, Ohio
Seitner, J. E., Sarasota, Fla.
Shackleton, J. R., Redondo Beach, Calif.
Shapiro, E., Peekskill, N.Y.
Sheppard, R., Ottawa, Ont., Canada
Sholtz, P. N., Yorktown, Heights, N.Y.
Shonnard, J. R., New York, N.Y.
Shott, A. J., Rochester, Mich.
Silbermann, G. F. H., Bayonne, N.J.
Sippach, R. W., St. Petersburg, Fla.
Smith, E. F., San Francisco, Calif.
Smith, E. G., Rotherham Yorkshire, England
Smith, E. S., New Orleans, La.
Smith, R. C., Jr., Springfield, N.J.
Smithberg, S. B., Inglewood, Calif.
Smokorowski, L. F., Toronto, Ont., Canada
Sneed, J. O., Miami, Fla.
Sperling, R. W., Buena Park, Calif.
Spiro, S. J., Chicago, Ill.
Spitz, M. E., Newton Highlands, Mass.
Stefansson, R., Altadena, Calif.
Sterns, R. B., Great Neck, L.I., N.Y.
Stolze, R. M., Marion, Iowa
Stomberg, A. V., Goteborg, North Sweden
Strachan, A. G., Elmhurst, L.I., N.Y.
Strobel, H. M., New York, N.Y.
Strong, W. J., Santa Ana, Calif.
Swarup, P., Montreal, Que., Canada
Sutherland, E. F., Cambridge, Mass.
Swientoniewski, E. J., Rome, N.Y.
Swiggett, R. L., Glen Cove, L.I., N.Y.
Thiede, P. W., Danville, Ill.
Thompson, J. G., Singapore, Malaya
Thomson, J. T., Jr., Dallas, Tex.
Tivy, R. C., Brockville, Ont., Canada
Topp, H. A., Jr., Fullerton, Calif.
Tuck, E. F., Redwood City, Calif.
Turrell, P. T., Romeo, Mich.
Ungar, A. J., Palo Alto, Calif.
Unger, E., Nuernberg, Germany
Van Brunt, F., Kensington, Md.
Vosefski, J. R., Webster, N.Y.
Waldner, M., Syracuse, N.Y.
Walker, J. R., Poughkeepsie, RD, N.Y.
Warczynski, R. G., Chicago, Ill.
Weedfall, R. W., Dallas, Tex.
Weil, W. M., Plainview, N.Y.
Weinrauch, A., Port Chester, N.Y.
White, R. J., Chicago, Ill.
Whiting, L., Alhambra, Calif.
Wichels, J., Jr., Oklahoma City, Okla.
Wilkinson, M. M., Dallas, Tex.
Wilser, R. E., Yorktown, N.Y.
Wilson, W. D., Lee's Summit, Mo.
Wood, J. A., Hillsboro, N.H.
Wood, L. S., Las Cruces, N.M.
Zimmerman, S. E., Baltimore, Md.

(Continued on page 112A)



Pilots Check Out
NAVIGATION RECEIVER ACCURACY

ARC Type H-14A Signal Generator Checks Omni/Localizer Equipment

ARC's H-14A Signal Generator provides a simple and dependable means of checking *omnirange* and *localizer receivers* in aircraft on the field, by sending out on the hangar antenna a continuous test identifying signal that blankets the field. Tuned to this signal, individual pilots or whole squadrons can quickly test their own equipment. Voice can be transmitted simultaneously with signal. The instrument will check 24 omni courses, omni course sensitivity, operation of TO-FROM meter and flag-alarms, left-center-right on 90/150 cps localizer, receiver frequency calibration, reciprocal course accuracy, and receiver output. The H-14A is also widely used for making quantitative measurements on the bench during receiver maintenance. Input power is 160 watts, 115 volts 60 cps.

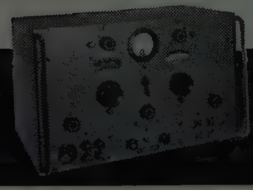
The H-16A Standard Course Checker measures the accuracy of the indicated omni course in ARC's H-14A or other omni signal generator to better than ½ degree. It features a built-in method of checking its own precision.

ARC's Type H-12 Signal Generator (900-2100 mc) is equal to military TS-419 U, and provides a reliable source of CW or pulsed rf. Internal circuits provide control of width, rate and delay of internally-generated pulses. Complete specifications on request.

Dependable Airborne Electronic Equipment Since 1928

Aircraft Radio Corporation BOONTON, NEW JERSEY

Miniaturized Automatic Direction Finders • Omni/Loc Receivers • Course Directors • UHF and VHF Receivers and Transmitters
LF Receivers and Loop Direction Finders • 10-Channel Isolation Amplifiers • 8-Watt Audio Amplifiers
Interphone Amplifiers • Omnirange Signal Generators and Standard Course Checkers • 900-2100 Mc Signal Generators



Type H-12
UHF Signal Generator

Type H-16
Standard Course Checker

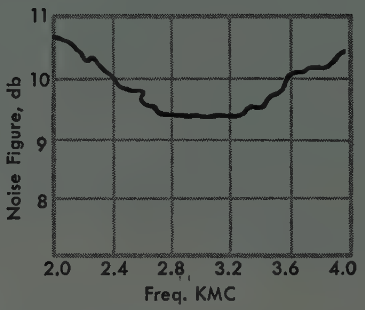
HUGGINS HA-37

LOW NOISE TWT AMPLIFIER

S-BAND—2.0 TO 4.0 KMC

6 TO 8 WEEKS DELIVERY

$1500.00



R. F. PERFORMANCE

FREQ. RANGE . . . . . . 2.0-4.0 KMC . . . 2.5-3.5 KMC
SMALL SIGNAL GAIN . . 25 DB (MIN.) . . . 25 DB (MIN.)
NOISE FIGURE . . . . . . 11 DB (MAX.) . . . 10 DB (MAX.)

POWER SUPPLY REQUIREMENTS

HELIX VOLTAGE . . . . 400 TO 500 VOLTS
COLLECTOR VOLTAGE . . . 400 TO 500 VOLTS
CATHODE CURRENT . . . . . 1.0 MA (MAX.)
HELIX CURRENT . . . . <20 UA
ANODE NO 1 VOLTAGE . . 0 TO 20 VOLTS
ANODE NO 2 VOLTAGE . . 0 TO 50 VOLTS
ANODE NO 3 VOLTAGE . . 0 TO 50 VOLTS
ANODE NO 4 VOLTAGE . . 0 TO −30 VOLTS
HEATER VOLTAGE . . . . . . 4.5 TO 6.3 VOLTS
HEATER CURRENT . . . . . . 0.9 AMPS (MAX.)
MAGNETIC FIELD . . . . . . 750 GAUSS

MECHANICAL CHARACTERISTICS

R.F. CONNECTORS . . . . . TYPE N MALE
D. C. CONNECTOR . . . . . WINCHESTER M9P
CAPSULE LENGTH . . . . . . 21½ INCHES
CAPSULE DIAMETER . . . . . 1.0 INCH
NET WEIGHT . . . . 1.0 POUND

THE HUGGINS HA-37 IS A BROADBAND AMPLIFIER OPERATING OVER THE 2000 MC BANDWIDTH WITH NO MECHANICAL OR ELECTRICAL ADJUSTMENTS REQUIRED. THE REDUCED NOISE FIGURE OVER THAT OBTAINABLE IN A STANDARD TWT AMPLIFIER MAKES THIS TUBE PARTICULARLY USEFUL IN INCREASING THE SENSITIVITY OF BROADBAND MICROWAVE RECEIVERS. CONSIDERABLY IMPROVED NOISE PERFORMANCE CAN BE OBTAINED OVER RELATIVELY NARROW SPECIFIED BANDS. PLEASE STATE SPECIFIC BANDWIDTH AND CENTER FREQUENCY OF INTEREST WHEN MAKING INQUIRY.

A general catalog giving detailed description of our products is available at your request on company letterhead.

manufacture
development
engineering
design
research

HUGGINS LABORATORIES
711 HAMILTON AVE. MENLO PARK 2, CALIFORNIA
DAvenport 6-3090 TWX Palo Alto 52

Membership

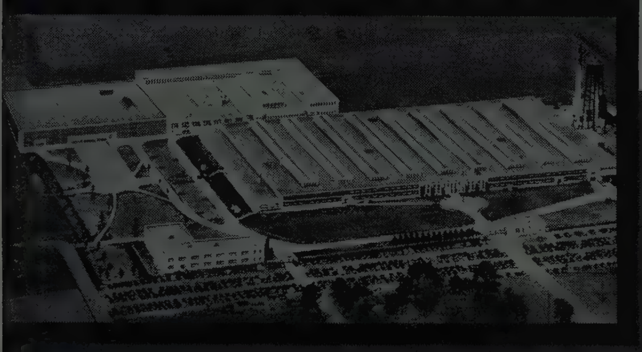
(Continued from page 110A)

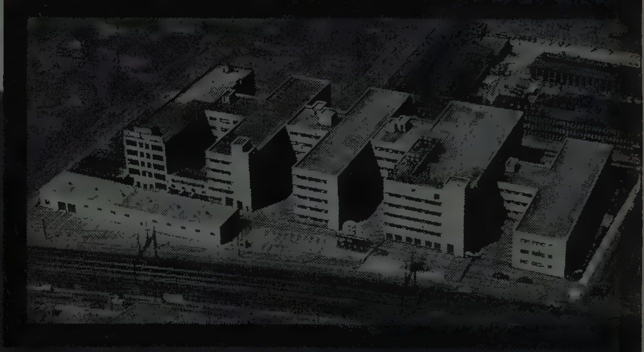
Admission to Associate

Allen, T. J., Jr., Seattle, Wash.
Andrews, R. C., Williamsport, Pa.
Ashley, C. A., Northridge, Calif.
Blicq, R. S., Winnipeg, Man., Canada
Bramham, K., Vancouver, B. C., Canada
Brown, D. C., St. Petersburg, Fla.
Bulliet, L. J., Rockford, Ill.
Burbank, R. W., Jr., North Dartmouth, Mass.
Byrne, F., Titusville, Fla.
Carey, D. R., Dallas, Tex.
Castelli, J. P., Arlington, Mass.
Cogianese, C. J., Dayton, Ohio
Cole, L. L., Jr., Beverly, Mass.
Crawford, E. M., Pittsburgh, Pa.
Cuccia, J. W., San Antonio, Tex.
De Maios, J., New York, N. Y.
Diermert, L., Mobile, Ala.
Dubois, V. G., Jr., San Antonio, Tex.
Dunn, H., Winnipeg, Man., Canada
Ebner, G. A., Fort Collins, Colo.
Fernandez, L. E., New York, N. Y.
Foster, F. L., Littleton, Colo.
Fisher, L. P., Jr., Birmingham, Mich.
Germann, F. G., Sr., North Charleston, S. C.
Greco, E., Rome, Italy
Green, H. L., Muncie, Ind.
Gupta, P. P., Bangalore, India
Hamby, H. W., Boaz, Ala.
Henry, C., Montreal, Que., Canada
Herrmann, P. A., Fairbanks, Alaska
Hill, A. R., Reading, Pa.
Holmes, C. M., Washington, D. C.
Holmes, C. W., Dayton, Ohio
Hyde, H., Jr., Bryn Mawr, Pa.
Kamil, T., Tel-Aviv, Israel
Katz, M., Newark, N. J.
Keel, R., Tampa, Fla.
Kiernozycki, L., Warszawa, Poland
Kim, M. K., Chin Hea, Korea
King, J. W., Williamsport, Pa.
Kirin, M. J., Santa Ana, Calif.
Kubilins, E. T., Newark, N. J.
Landstein, M., Brooklyn, N. Y.
Liddicoat, W. L., Vancouver, B. C., Canada
Linster, J. J., Jr., Dickinson, N. D.
Maher, W. F., Oreland, Pa.
McHugh, D. E., Toronto, Ont., Canada
Medina, G. R., New York, N. Y.
Moore, J. B., Jr., Norfolk, Va.
Muhlberger, J. G., Alamogordo, N. M.
Nerhag, O., Stockholm, Sweden
Nieto, J. V., Mexico, D.F., Mexico
Nouel, C. C., Laguaira, Venezuela
Olson, V. E., Grand Rapids, Mich.
Owens, D. A., Springfield, Ill.
Patterson, A. R., Arcadia, Calif.
Pfeifer, E., Flint, Mich.
Pires, M. D., Honolulu, Hawaii
Radman, N. T., Albuquerque, N. M.
Robinson, D. A., Dallas, Tex.
Ross, J. A., Silver Spring, Md.
Rundquist, C. F., Orlando, Fla.
Runyan, R. W., Pomona, Calif.
Sawyers, E. R., St. Petersburg, Fla.
Shlank, W. I., New Haven, Conn.
Smoller, R. G., St. Martin, Que., Canada
Sumpter, R. C., St. Petersburg, Fla.
Talarczyk, A. R., Minneapolis, Minn.
Thinnes, R. L., Dayton, Ohio
Thurmond, J. G., Houston, Tex.
Vetter, C. R., Dayton, Ohio
Watson, G. E., Tulsa, Okla.
White, D. D., San Antonio, Tex.
Yost, H. T., Wichita, Kans.
Zacharellis, G., Bayonne, N. J.
Zapp, K. A., Dallas, Tex.
Zimmerman, M. G., Cocoa, Fla.

SINGER*

MILITARY PRODUCTS DIVISION





Behind This Symbol Is An Advanced Concept Of Specialized Electronic Service

Creative research, developmental skills, and precision production capacity are behind this new symbol of The Singer Manufacturing Company's *Military Products Division.*

Here are the research skills of Haller, Raymond & Brown, Inc., the electronic and electrical experience and facilities of Diehl Manufacturing Company, the more than half a million square feet of mechanical and electro mechanical productive facilities of Singer-Bridgeport.

This team, which comprises the Singer Military Products Division, can supply specialized electronic systems or products from concept to production. Or it can operate efficiently as a subcontractor to supply precision parts in large or small quantities, at a practical cost. For a new outlook on defense procurement, write *The Singer Manufacturing Company, Military Products Division, 149 Broadway, New York 6, N. Y.*

THE SINGER MANUFACTURING COMPANY
Military Products Division
149 BROADWAY, NEW YORK 6, N. Y.

SINGER MILITARY PRODUCTS DIVISION

*A TRADEMARK OF THE SINGER MANUFACTURING COMPANY

. . . important evidence of

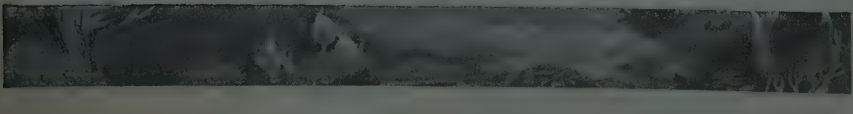
Vitro leadership in systems engineering coordination

Our contributions to the system coordination of the Polaris program are another important milestone in Vitro's forward march in the field of guided missile and underwater weapon systems.

Polaris is only one of several exciting projects being tackled by our professional staff. If you are an experienced engineer or physicist and would like to explore the unusual combination of advantages available at Vitro, please . . .

Write to: Manager, Professional Employment
Vitro Laboratories, Dept. 305
14000 Georgia Avenue, Silver Spring, Maryland

Vitro LABORATORIES
Division of Vitro Corporation of America



Positions Open

The following positions of interest to IRE members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. . . . .

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

Proceedings of the IRE
1 East 79th St., New York 21, N.Y.

PROFESSOR—ASSOCIATE PROFESSOR

Academic positions in electrical Engineering and physics are open at Lowell Technological Institute, Lowell, Mass. The openings are for associate and full professor for teaching at both the undergraduate and graduate level. Salary is based on 9 months of teaching, with additional income available from night or summer teaching, and research work in solid state, radio telescope, and instrumentation. Inquiry should be sent to C. A. Stevens, Head, Dept. of Electrical Engineering.

VHF AND UHF DESIGN ENGINEER

Small manufacturer needs experienced engineer to design, debug and place in production VHF and UHF equipment, to supervise development and production test personnel. Opportunity is what you make it as a key engineer of this organization. Location in small community of professional people in mountains of Middle Atlantic state. Salary about $8,000 plus stock option. Box 1072.

INSTRUCTOR AND ASSISTANT PROFESSOR

For those interested in teaching fundamental electric and electronic subjects. Openings for fall semester beginning September 1958. Salary depends on qualifications. New building and equipment. Opportunity for advancement and further study. 9 month academic year. Part time evening work available. Health insurance and pension plan. Send complete resume to Professor I. L. Kosow, Dept. Head, Electrical Technology, Staten Island Community College, 50 Bay Street, Staten Island 1, New York.

RESEARCH COLLABORATOR OR ASSISTANT PROFESSOR

Academic appointment is available as Research Collaborator or Assistant Professor to supervise designing, fabricating, and maintaining specialized electronic equipment for research in chemistry, physics and engineering. A properly qualified person will, if he desires, have the opportunity to participate in electronic research or teach. Salary range of $7,000. Annual appointment with 1 month vacation. Application or further inquiry, apply to Dean Virgil W. Adkisson, Research Coordinator, University of Arkansas, Fayetteville, Arkansas.

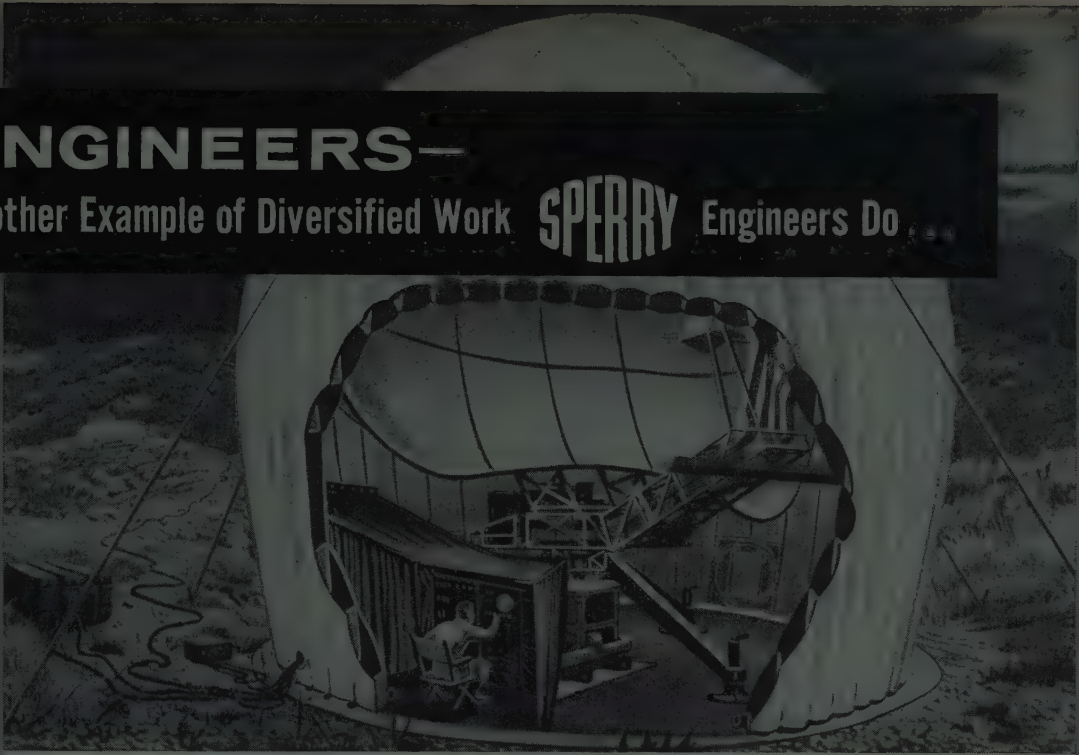
TRANSISTOR AND MAGNETIC AMPLIFIER CIRCUIT ENGINEERS

For design work on regulated power supplies. Opportunity with rapidly expanding firm. Write Philip Diamond, President, Perkin Engineering Corp., 345 Kansas St., El Segundo, Calif.

(Continued on page 117A)

ENGINEERS—

Another Example of Diversified Work SPERRY Engineers Do . . .



As fast on the move as a fighting Marine is the new "TEW" (tactical early warning) radar system being developed by Sperry for the Marine Corps. Only one-fourth the size and weight of conventional radars, TEW is easily carried to battle areas by helicopter, cargo plane, truck or amphibious vehicle. Within two hours, an 18-man crew can erect the TEW system and place it in operation.

With its very long range and portable construction, TEW provides the Marines with the means to extend the nation's defense perimeter and insure added protection for key installations and outposts.

If you're interested, not in an engineering job, but in an engineering CAREER, check Sperry—

Sperry Gyroscope also stands for steady growth. Not just for the company—but for its engineers. Sperry engineers are career engineers, working on projects—like TEW—that are creative, interesting, important. They stay, and grow, with us. That's why over 2,600 Sperry employees are 15-year men. And—today we're expanding, diversifying more than ever. If engineering is your life's work—check Sperry.

Openings in many specializations including the following:

INERTIAL NAVIGATION SYSTEMS
DOPPLER NAVIGATION • RADAR RECEIVERS
RADAR TRANSMITTERS • INFRARED SYSTEMS
PULSE CIRCUITS • TIMING CIRCUITS
ELECTRONIC PACKAGING
TRANSISTOR CIRCUITS
For Pulse & Video Applications
MICROWAVE ANTENNA DESIGN

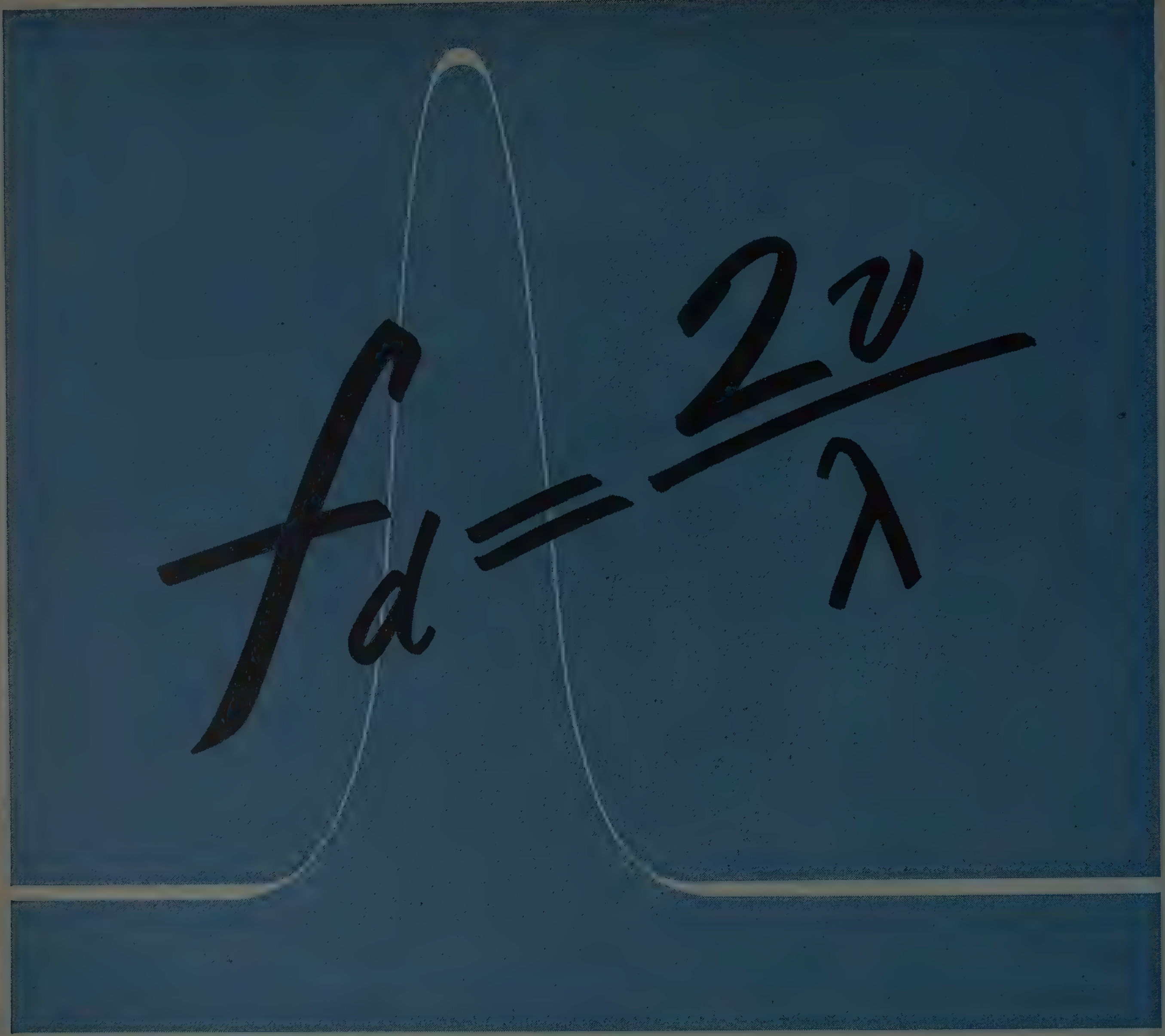
Confidential Interviews

Contact Mr.
J. W. Dwyer
Employment Manager

•

Saturday Interviews
8 A.M.-1 P.M.
Arranged by Appointment

SPERRY
GYROSCOPE COMPANY
Division of Sperry Rand Corp.
Great Neck, Long Island, N.Y.
Fieldstone 7-3665



DOPPLER NAVIGATION SPECIALISTS

Work on advanced doppler radar navigation and guidance projects at Raytheon.

Some of the most interesting and vital projects of the day are now in the works at Raytheon's Maynard Laboratory.

Challenging assignments are given to engineers with specialized radar experience in doppler navigation and guidance systems... and to others with backgrounds in radar interested in working with these new systems.

Are you a circuit design engineer, microwave design engineer, product design engineer, or systems engineer with radar experience?

PLEASE CALL COLLECT. Ask for John J. Oliver at TWin Oaks 7-2945, Ext. 246, or write him for details. He'll be glad to arrange an appointment at your convenience.

RAYTHEON MANUFACTURING COMPANY
Maynard Laboratory
P. O. Box 87P, Maynard, Massachusetts

RAYTHEON

Excellence in Electronics

Positions Open

(Continued from page 114A)

ASSOCIATE PROFESSOR

Associate Professor for Electrical Engineering Dept. Ph.D. degree preferred. Opening in electronics. Salary commensurate with experience and education. Position available September 1958. Write head, Electrical Engineering Dept., South Dakota School of Mines and Technology, Rapid City, South Dakota.

ASSISTANT OR ASSOCIATE PROFESSORS

MS. minimum with interest in circuits, computers or servos. Land grant school in the midwest. Salary open. Teach undergraduate and graduate courses through MS. Write Chairman, E.E. Dept., North Dakota State College, Fargo, North Dakota.

ASSISTANT TO CHIEF ENGINEER

Assistant to Chief Engineer, midwest station. E.E. degree, demonstrated technical ability as well as administrative and organizational experience; salary open. Box 1075.

CIRCUIT DESIGN ENGINEER

Senior circuit development engineer for sweep circuits, power supplies, amplifiers. Located in the heart of the San Francisco Bay area; electronics industry. Moving allowances. Send resume to Menlo Park Engineering, 721 Hamilton Ave., Menlo Park, Calif.

ELECTRICAL ENGINEER

Effective immediately the following position is available in our machine design and development group; degree in electrical engineering; 2 to 3 years' experience in design and development of electro-mechanical machines and equipment. Apply Personnel, Assistant Industrial Relations, Haloid Xerox Inc., Rochester 3, N.Y.

COMPUTER ENGINEERS

Electronics Engineer with 5 to 7 years' experience in digital computer pulse circuitry, utilizing solid state components. Knowledge of vacuum tube techniques and machine logic required. Salaries open. Send resume to Underwood Research and Engineering Laboratory, 56 Arbor St., Hartford, Conn.

COMPUTER LOGICAL DESIGNER

Must have degree in engineering or mathematics plus 5 years' experience in digital computers systems studies and logical design. Knowledge of business data-processing systems helpful. Salary open. Send resume to Underwood Research Engineering Laboratory, 56 Arbor St., Hartford, Conn.

COMMUNICATIONS ENGINEER

Opening for graduate engineer with a minimum of 5 years' design and systems background in mobile communications. Must be capable of assuming complete technical and administrative control over assigned projects. In reply, please state education, experience, age and salary requirements. All replies in strict confidence. Box 1076.

(Continued on page 120A)

engineers and physicists:

learn how "TALENT GROWS at EMERSON ELECTRIC"

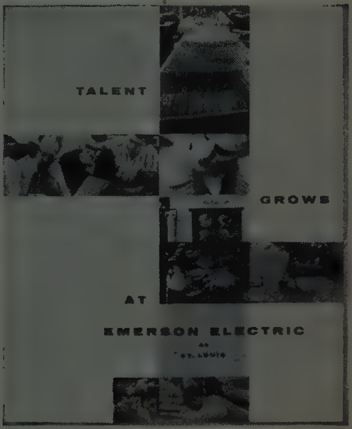
COME ALONG on this illustrated tour of Emerson Electric's engineering facilities. Meet our engineering staff as they meet the challenges of complex problems related to advanced electronics and missiles projects. Find out about our operating philosophy, diversified projects, size, benefits, educational opportunities, our future and *yours!*

We believe we offer the wide-open challenges and career opportunities you've been looking for. This new brochure is our way of introducing ourselves and our operations.

SEND TODAY for colorful, illustrated brochure using convenient coupon, or simply address a letter or card to Andy Depke Engineering Employment Supervisor. There is no obligation.

Electronics and
Avionics Division
8100 W. Florissant
St. Louis 21, Mo.

EMERSON
ELECTRIC



ANDY DEPKE
EMERSON ELECTRIC
8100 W. FLORISSANT
ST. LOUIS 21, MO.

Please send me illustrated brochure:
"Talent Grows at Emerson Electric"

Name______________________________
Address______________________________
City________________Zone_____State________

Advanced missile and space projects

require Engineers

and Scientists to work on

THE FRONTIERS OF SPACE

Lockheed Missile Systems Division, recently honored at the first National Missile Industry Conference as "the organization that contributed most in the past year to the development of the art of missiles and astronautics," holds such important, long-term projects as the Navy Polaris IRBM, Earth Satellite, Kingfisher (Q-5) target missile for the Army and the X-7 ramjet test vehicle for the Air Force.

To carry out such complex projects, the frontiers of technology in all areas must be expanded. High-level engineers and scientists are needed now for responsible positions in our Research and Development laboratories and in our project organizations.

If you are experienced in physics; mathematics; chemistry or one of the engineering sciences, your inquiry is invited. Please write Research and Development Staff, Sunnyvale 12, California. (For the convenience of those living in the East and Midwest, offices are maintained at Suite 745, 405 Lexington Ave., New York 17, and at Suite 300, 840 N. Michigan Avenue, Chicago 11.)

Lockheed / MISSILE SYSTEMS DIVISION

SUNNYVALE • PALO ALTO • VAN NUYS • SANTA CRUZ • COOKE AIR FORCE BASE, CALIF. • CAPE CANAVERAL, FLORIDA • ALAMOGORDO, NEW MEXICO

ECHNOLOGY

FLIGHT IN THREE MEDIUMS

Several things set the Polaris apart from other outer space weapons in the ballistic missile category, for the Polaris program involves a wholly new concept of weaponry.

1. It will be dispatched from beneath the surface of the sea.
2. It will be radically smaller than currently developed land-launched missiles, yet its payload will be as effective and its range the same as other IRBMs.
3. It will be the first operational outer space missile to employ solid fuel as a propellant.
4. It will travel through three mediums in a single flight—water, air and outer space.
5. Its launching base—a submarine—is not fixed but a mobile vehicle.

OUTER SPACE PROGRAM

Very little can be said about the Earth Satellite program at this time except that its success will necessitate advancing the state of the art in all sciences.

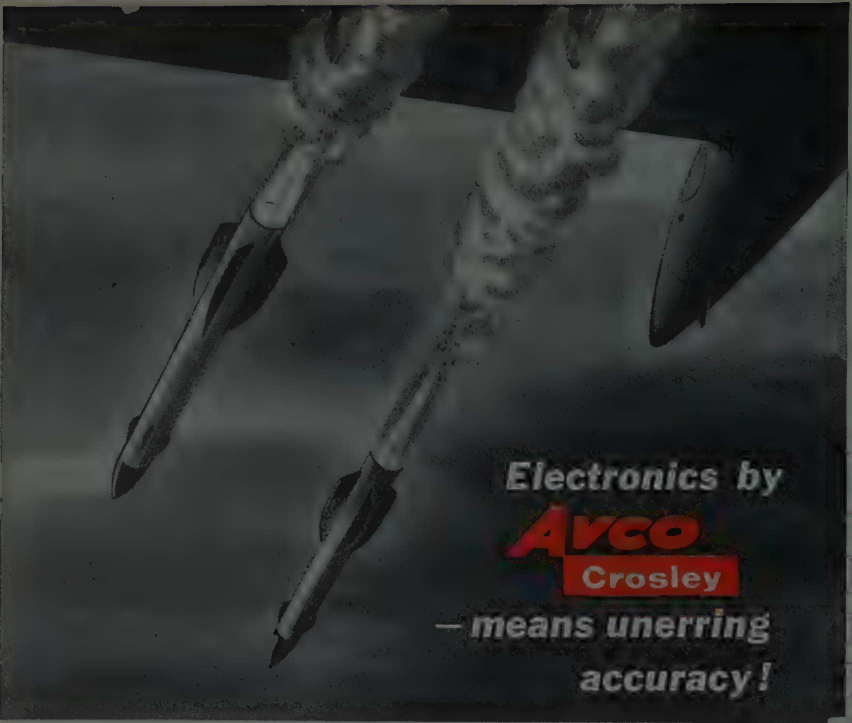
The Earth Satellite Project is perhaps the most sophisticated outer space program to reach the "hardware" stage in the U.S. today.

ENEMY SIMULATOR

The Lockheed Kingfisher Q-5 is the nation's fastest target missile, developed for the Air Force to test the accuracy of our newest supersonic weapons.

It is a ramjet target vehicle with Mach 2-plus capabilities. The Q-5 not only has speed to match the defensive missiles, but can also simulate a vast array of supersonic enemy missiles and airplanes attacking from great height. It is instrumented to score near misses and even theoretical hits without itself being destroyed.

It is recoverable from flight by parachute to be flown again, permitting weapon system evaluation to be conducted at greatly reduced cost.



Engineers!

COME WITH US AND REACH YOUR CAREER TARGET!

CROSLEY offers you exciting challenges in a variety of interesting and expanding projects. We sincerely believe your professional growth will be given a chance to develop to its fullest extent when you and CROSLEY join forces as "Partners In Opportunity".

HERE ARE FIELDS OF CURRENT ACTIVITY:

1. Ground Radar
2. Airborne Defense Systems
3. Antenna and Micro-Wave Equipment
4. Computer and Analytical Services
   (DESIGN AND DEVELOPMENT)
   (PROGRAMMING AND APPLICATION)
5. Communications
   (AIRBORNE TRANSMITTERS AND RECEIVERS)
6. Airborne Fire Control
7. Servo-Mechanisms
8. Transistorized Equipment
9. Guided Missiles
10. Infra-Red Research

Write us for complete details. We'll send you literature and we'll tell you about the advantages of family living in Cincinnati—"Queen City of the West, Closest to the Heart of America." There are numerous company benefits and you will be paid generous relocation expenses.

Send your resume to:

Personnel Manager
Dept. 24

AVCO
Crosley

AVCO MANUFACTURING CORPORATION
CROSLEY DIVISION
1329 Arlington St. Cincinnati 25, Ohio

Flight Controls Design Specialists

You will guide the development of manual and automatic flight controls for high performance VTOL jet aircraft. Openings in the following areas: Automatic Flight Control Systems, Flight Instrumentation, Test Equipment Design, Systems Testing, Manual Flight Control Systems.

Send resume to: Engineering Employment Supervisor, Dept. 0-40, BELL AIRCRAFT CORPORATION, P.O. Box 1, Buffalo 5, New York.

Positions Open

(Continued from page 117A)

PHYSICISTS, CHEMISTS, ENGINEERS

Positions now open for research in each of the following fields: gas discharges, electron tube devices including storage tubes, radiation effects on dielectrics, and semiconductors. Send resume to Radiation Research Corp., 1114 First Ave., New York 21, N.Y.

PROJECT ENGINEERS

Immediate openings are available for Project Engineers in microwave communications, instrumentation and telemetry. Openings are also available for young graduate engineers with 1 to 5 years' experience. Excellent employee benefits with young growing company. Send resume to Ling Systems Inc., 11949 Vose St., North Hollywood, Calif.

ASSISTANT OR ASSOCIATE PROFESSORS

Assistant or Associate Professors with Ph.D. Large graduate program. Income $9,000-$12,000 with research. Ideal mountain climate. Box 1077.

INSTRUCTORS AND RESEARCH ENGINEERS

Instructors and research engineers to work for D.Sc. at University of New Mexico. Large graduate program assures variety of available courses. Chairman, E.E. Dept., University of New Mexico, Albuquerque, New Mexico.

ELECTRONIC ENGINEER

Electronic Engineer to teach lecture and laboratory courses. Up-to-date knowledge of the field required. Working and living conditions excellent; salary and opportunity very attractive. Write to Dean of Engineering, California State Polytechnic College, San Luis Obispo, Calif.

ELECTRONIC ENGINEER

Electronic Engineer, for nuclear physics research laboratory . . . for design and development of equipment of varied nature, from D.C. to .001 microsecond pulses. Wide experience useful, but will consider younger man of promise. Salary depends on qualifications; compares favorably with industry. Excellent working conditions and atmosphere. Write, stating age, education, experience and salary desired to University of Penna. Personnel Office, 3025 Walnut St., Phila. 4, Pa. or telephone EVergreen 6-0100 ext. 8143.

ENGINEER

Engineer to open branch office of Manufacturers Reps. Agency in upper New York state or Boston area, on a partnership basis. Engineering background required, digital background desirable but not essential. Principal has topnotch manufacturers of digital and analog systems and components. Wants to expand. Please send resume to Box 1078.

TEACHERS

Excellent opportunity is available in a new expanding department. Location is at medium sized university in the midwest devoted primarily to undergraduate teaching. Rank and salary commensurate with qualifications. Appointment is available beginning September 1958. Send complete resume to Box 1079.

work in the fields of the future at NAA

ELECTRONICS ENGINEERS

Work on America's most advanced weapon systems

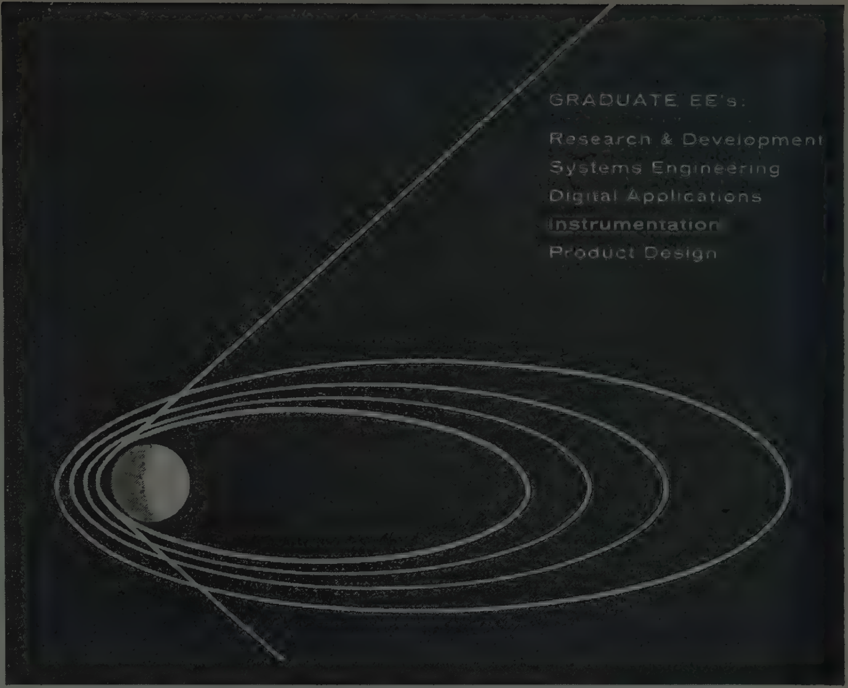
The WS-110A and WS-202A are typical of the top-level projects currently under way at North American. NAA's work on these far-advanced weapon systems has created outstanding career opportunities for engineers qualified in Flight Control Analysis, Reliability Analysis, Flight Simulation, and Systems Analysis.

We have immediate openings in applied research on radome development, antenna development, infrared, and acoustics.

Minimum requirements are actual experience plus B.S. and advanced degrees in E.E. and Physics.

For more information please write to: Mr. B. H. Stevenson, Engineering Personnel, North American Aviation, Inc., Los Angeles 45, California.

THE LOS ANGELES DIVISION OF
NORTH AMERICAN AVIATION, INC.



TODAY'S OPPORTUNITIES

with General Electric's Missile Guidance Section

CARRY IMPORTANT RAMIFICATIONS FOR SPACE TECHNOLOGY

Despite the magnitude of the undertaking, guiding a vehicle on a >428,000 mile return trip to the Moon...or directing an interplanetary probe into Mars' orbit depends fundamentally upon the basic technologies already developed to guide surface-to-surface ballistic missiles into their trajectories.

The great technical challenges of guidance for space exploration lie in the unprecedented accuracies, reliabilities and long operative life-spans that must be engineered into the guidance systems.

ENGINEERS and SCIENTISTS at G.E.'s Missile Guidance Section—with their broad experience in creating highly reliable ICBM systems are well prepared to deal creatively and effectively with space problems.

If You Are Interested in Joining a Group With These Capabilities for work in frontier areas, look into the positions now open with the Section, on a number of stimulating, advanced projects.

Significant experience in 1 or more of these areas is required:

Radar
Communications
Countermeasures
Antenna Design
Transistors
Telemetry
Microwaves
RF Circuitry
Digital Computers
Test Operations
Engineering Analysis

Forward your resume in strict confidence to
Mr. E. A. Smith, Dept. 8-F
MISSILE GUIDANCE SECTION
GENERAL ELECTRIC
Court Street, Syracuse, N. Y.

LIFELINE FOR

THE LEAP INTO OUTER SPACE

Our only link with outer space is the advanced Communications System. Our progress in space technology has become dependent on solving the vast network of new problems which the Space Age has imposed on the field of Communications.

To meet these problems the Hughes Communications Systems Laboratories is drawing upon its continuing efforts in the field of Global Airborne Communications. Such newly devised Hughes hardware, at left, for example, illustrates the use of high-reliability wire wrapping to replace soldered connections and the use of inexpensive miniaturized "cordwood" circuit modules to make possible high component density.

New methods, such as Hughes-pioneered digital techniques, are being formulated to achieve the long-range goal of developing communications systems capable of deflecting their signals from meteors, artificial satellites, and even the moon. Still other methods are being developed for systems which will transmit intelligence through media impervious to radio frequencies by modulating frequencies far up the electromagnetic spectrum.

Advanced thinking, diversification, and expansion are also taking place in other areas of the Research & Development Laboratories, of which Communications is a part . . . in Hughes Products, the commercial activity of Hughes . . . in Hughes Fullerton, where three-dimensional radar systems are under development . . . in Hughes El Segundo, the manufacturing facility for complex electronics systems . . . and in Hughes Tucson, where guided missiles are manufactured.

Never before have the opportunities at Hughes been more promising!

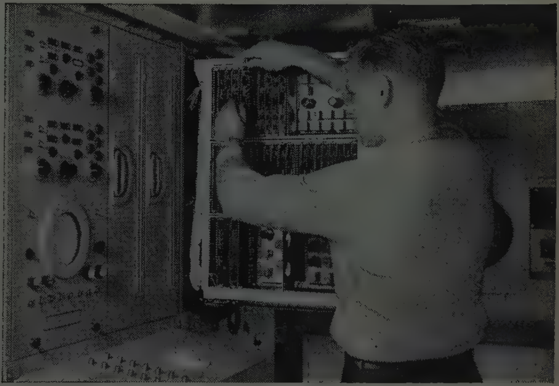
Electromagnetic positioning of cutting edges is directed by this etched metal bar, a significant innovation which aided in the Hughes Products development of the first all-electronically controlled machine tool line.

Data processors under development at Hughes Fullerton will monitor the action of hundreds of aircraft and store the changing tactical situation in electronic memories for high-speed assignment of defense weapons. ▶

New commercial and military contracts have created an immediate need for engineers in the following areas:

- Nuclear Electronics
- Microwaves
- Communications
- Reliability
- Circuit Design
- Field Engineering
- Vacuum Tubes
- Crystal Filters
- Systems Analysis
- Computer Engineering

Write in confidence to Mr. Phil N. Scheid,
Hughes General Offices, Bldg. 6-X, Culver City, California.



the West's leader in advanced electronics

HUGHES

© 1958, HUGHES AIRCRAFT COMPANY

HUGHES AIRCRAFT COMPANY
Culver City, El Segundo,
Fullerton and Los Angeles, California
Tucson, Arizona

Wescon show. Visit our booths 1401, 1402, 1812, and 1813 or the Hughes recruiting suites at the Chapman Park Hotel.

An Invitation To Join ORO...Pioneer In Operations Research

Operations Research is a young science, earning recognition rapidly as a significant aid to decision-making. It employs the services of mathematicians, physicists, economists, engineers, political scientists, psychologists, and others working on teams to synthesize all phases of a problem.

At ORO, a civilian and non-governmental organization, you will become one of a team assigned to vital military problems in the area of tactics, strategy, logistics, weapons systems analysis and communications.

No other Operations Research organization has the broad experience of ORO. Founded in 1948 by Dr. Ellis A. Johnson, pioneer of U. S. Opsearch, ORO's research findings have influenced decision-making on the highest military levels.

ORO's professional atmosphere encourages those with initiative and imagination to broaden their scientific capabilities. For example, staff members are taught to "program" their own material for the Univac computer so that they can use its services at any time they so desire.

ORO starting salaries are competitive with those of industry and other private research organizations. Promotions are based solely on merit. The "fringe" benefits offered are ahead of those given by many companies.

The cultural and historical features which attract visitors to Washington, D. C. are but a short drive from the pleasant Bethesda suburb in which ORO is located. Attractive homes and apartments are within walking distance and readily available in all price ranges. Schools are excellent.

For further information write:
Professional Appointments

OPERATIONS RESEARCH OFFICE
ORO The Johns Hopkins University
6935 ARLINGTON ROAD
BETHESDA 14, MARYLAND

Positions Wanted

By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The IRE publishes free of charge notices of positions wanted by IRE members who are now in the Service or have received an honorable discharge. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion and the maximum number of insertions is three per year. The IRE necessarily reserves the right to decline any announcement without assignment of reason.

Address replies to box number indicated, c/o IRE, 1 East 79th St., New York 21, N.Y.

ENGINEER

10 years' broad background includes electronic instrumentation for medical and industrial applications as well as component development. Experienced tube and transistor circuit designer. Knowledge vacuum technology. Presently Project Engineer. Desires stable, non-military engineering position in keeping with background. Married, one child. BSEE. 1948, MSEE. 1954. Box 1048 W.

SALES ENGINEERING OR MARKET ANALYSIS

BSEE. 9 years' experience including Sales Manager of small electronic company, Sales Engineer, Applications Engineer, Project Engineer, Air Force Air Electronics officer. Supervisor of maintenance and Navy Electronic Technician. Age 31, married, 1 child. Desires opportunity leading to supervisory responsibility. Box 1051 W.

COMPONENTS ENGINEER

BSEE. 1950. Electrical Engineer. Experienced in aircraft and missile electronics design and mechanical design. Employment desired in manufacturing processes for electronic components; vacuum plating process, chemical etch process, plastics extrusions and moulding; high temperature ceramic ovens; and design of special production machines. Southern area. Box 1052 W.

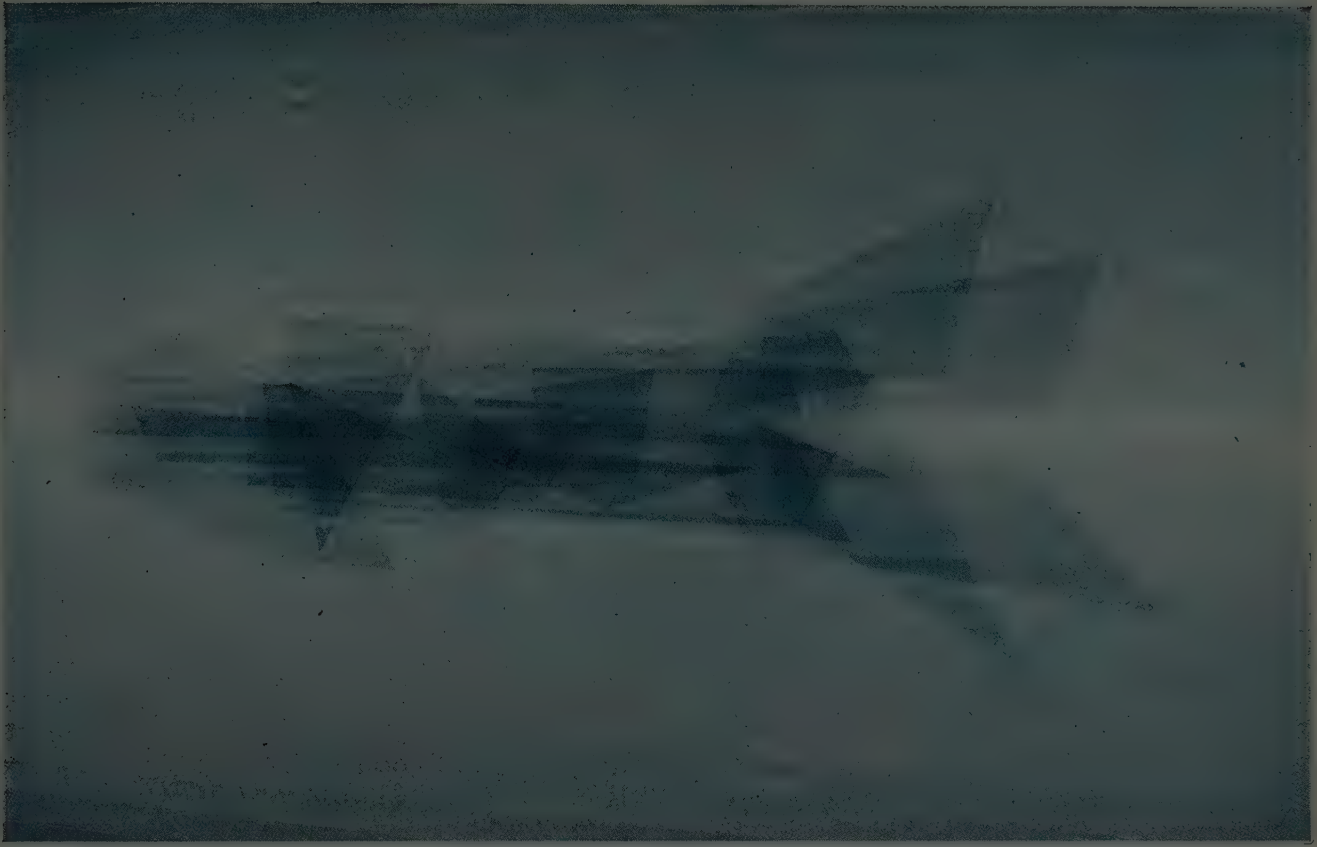
PHYSICIST—ENGINEER

Physicist BS. 1958. 1 year experience in solid state research laboratory as student engineer. Naval Electronics Technician Class "A" school and 2 years' experience in radar maintenance. Age 25, married, 1 child. Presently located in Phila. Will relocate. Box 1057 W.

ELECTRICAL ENGINEER

M.I.T. graduate Electrical Engineer with sales and engineering experience. Wants lines to represent in the New England area. Please write Box 1058 W.

(Continued on page 126A)



"ROCKETS", one of a series of paintings by Simpson-Middleman, a team of artists with the rare ability to translate scientific fact into creative imagery. Here, the rocket's blast and its guiding beam are thought of as a single stream of light through the center. Darks and lights of definite shape in a weak visual vector field are relied on to suggest the dynamics caused by the acts of the servo-mechanisms in making their adjustments. Painting courtesy John Heller Gallery, Inc.

man in space

Boeing has planned ahead to meet the problems and develop the potentials of the space age—through organizational structure, expanded facilities and advanced fundamental research.

The Boeing Systems Management Office develops proposals and provides management for all projects employing space-age techniques. Advanced studies include boost-glide vehicles, anti-ballistic missile area defense systems, air-to-surface missiles, and manned and unmanned space vehicles.

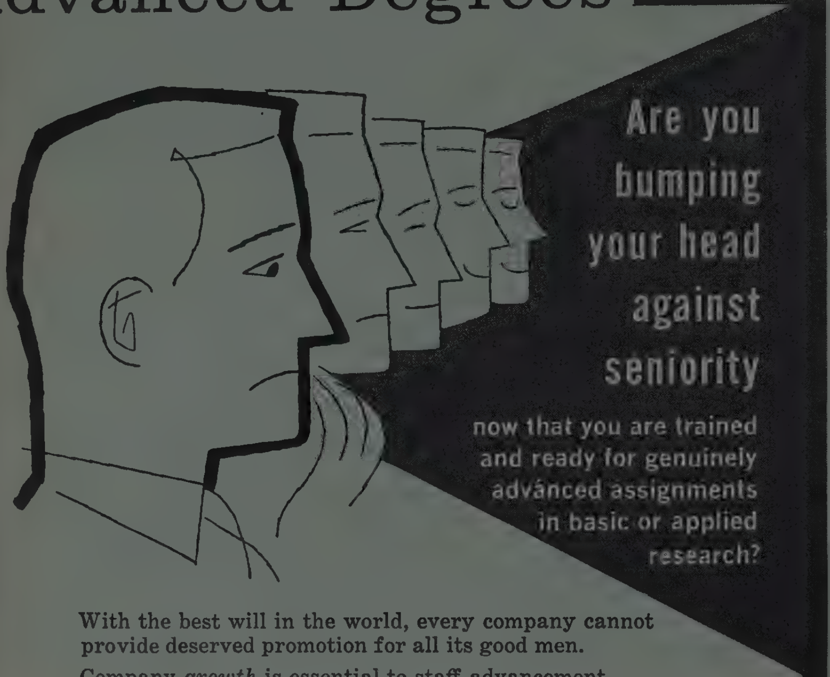
Boeing's space-age orientation, its tremendous technical and research capability, and its outstanding weapon system management experience earned for the company and its associates an Air Force assignment for Phase I development of Dyna-Soar. This is a weapon system based on a manned boost-glide vehicle that will orbit at speeds approaching 18,000 miles an hour, and be capable of re-entering the atmosphere and making a normal landing.

Dyna-Soar and other space-age projects at Boeing offer exceptional opportunities to engineers of all categories, and to physicists, mathematicians and scientists. Drop a note now to Mr. Stanley M. Little, Dept. G-78, Boeing Airplane Co., Seattle 24, Wash.

BOEING

PHYSICISTS...MATHEMATICIANS...EE's

Scientists and Mathematicians with Advanced Degrees


Are you bumping your head against seniority
now that you are trained and ready for genuinely advanced assignments in basic or applied research?

With the best will in the world, every company cannot provide deserved promotion for all its good men.

Company *growth* is essential to staff advancement.

Company emphasis on research and development in forward areas is necessary, to provide able men with the assignments and facilities that make scientific discoveries possible.

IF YOU FIND YOUR PROGRESS SLOWED at this time, look into the opportunities available for highly trained, creative men in:

Basic and Applied Research at SYLVANIA'S New Amherst, N. Y. Engineering Lab.

Broad investigations leading to advances in communications concepts and techniques are under way in such areas as:

• Interplanetary Communications Systems • Composition of Space • Statistical analysis of noise & fading • Optimum signals or communication channels • Efficient applications of redundancy • Physics of the communication channel • Error correction & error detection • Theoretical & applied probability theory • Physical basis of communication • Wave propagation in missile & satellite environments.

The Amherst Laboratory is expanding. New facilities were completed only a few months ago and plans call for a substantial increase in the professional staff. There is practically no limit to how far an original thinker can go in advanced communications with Sylvania.

Sylvania is seeking SCIENTISTS AND ENGINEERS WHO CAN DEFINE THEIR OWN PROBLEMS (rather than solve problems formulated by others) AND WORK WITH A MINIMUM OF SUPERVISION.

AN ADVANCED DEGREE IS REGARDED AS HIGHLY DESIRABLE FOR THE WORK OUTLINED. Also depth of experience in such areas as: Experimental & Theoretical Physics, Electronic Systems Development, Information Theory, Probability Theory, Game Theory, Stochastic Processes.

Please Write to: Dr. Robert Malm
Amherst Engineering Laboratory
ELECTRONIC SYSTEMS DIVISION
SYLVANIA
SYLVANIA ELECTRIC PRODUCTS INC.
1140 Wehrle Drive, Amherst 21, New York

Positions Wanted

By Armed Forces Veterans

(Continued from page 124A)

INSTRUMENTATION SALES

21 years' experience in all phases of electronic instrumentation. This includes engineering, sales, management and production. Interested in position in sales management, application engineering or general management. Age 39, married, 2 children. Will relocate. Box 1059 W.

ELECTRONIC ENGINEER

Bachelor of Science in mathematics, Tulane University 1957. Desires career position in electronics. Veteran with military electronics experience. Age 27; single. Remuneration of secondary importance if working conditions are interesting. Special interest in electronic computers. Box 1060 W.

MARKETING

Uniquely-qualified man with know-how in marketing of electronic products. Fully versed in selling to commercial and consumer markets. Diversified background includes advertising and marketing research. Personable with good appearance. Radio amateur. Some engineering education plus degree in marketing. Seeks responsible opportunity to increase your sales. Box 1061 W.

ELECTRONIC TECHNICIAN

Ten years' aircraft radio and electronics experience on commercial air lines. 1½ years' digital computer experience. Past five years spent doing instruction and part-time supervision. Hold 1st class radiotelephone license. Box 1062 W.

ELECTRONIC ENGINEER

Liaison Engineer engaged in contractual and technical administration of multi-million dollar subcontract desires position in project administration or liaison. BBA, MBA. 8 years diversified electronic experience including test equipment design and systems engineering. Schooled in military electronics. Box 1070 W.

ENGINEER

Seven years' transformer experience including design, production, test and the writing of specifications for transformers and their materials. Special experience in EPOXY resin embedment and in close tolerance reactor work. Box 1071 W.

ELECTRONICS EXECUTIVE

Graduate with twelve years' experience in communications and controls. Leader. Desires challenge. Box 1072 W.

Use your
IRE DIRECTORY!
It's valuable!

SR. ELECTRICAL PRODUCT ENGINEER

. . . for design of expanding Norelco product line

PHILIPS ELECTRONICS, Inc.—engaged in developing instrumentation for research, materials control and production—offers a senior engineer an unusual opportunity to perform electronic design, establish test specifications and supervise construction of prototype units, including follow-through on manufacture and assembly problems as they relate to engineering design.

Background should include:

- . . . at least 5 years' experience in electro-mechanical precision instrumentation
- . . . knowledge of digital and pulse circuitry, component selection and electronic equipment packaging

Typical product experience might cover power supplies, amplifiers and computer circuitry.

Please write in full confidence, stating salary requirements, to:

Mr. Robert L. Ford
Personnel Manager
PHILIPS ELECTRONICS, Inc.
750 South Fulton Avenue
Mt. Vernon, New York

SCIENTISTS ENGINEERS

CALIFORNIA

offers you and your Family

- A world center of the electronic industry for CAREER ADVANCEMENT
- The High Sierras and the Pacific Ocean for RECREATION
- Some of the nation's finest public schools for your CHILDREN
- World Famous Universities for ADVANCED STUDY
- MAJOR CULTURAL CENTERS

while living in such places as
Exciting San Francisco
Fabulous Southern California
Cultural Palo Alto

companies pay interview, relocation and agency expenses

submit resume in confidence to:

PROFESSIONAL & TECHNICAL
Recruiting Div. of
Permanent Employment Agency
825 San Antonio Rd.
Palo Alto, Calif.

ENGINEERS • SCIENTISTS

R&D opportunities in CALIFORNIA with SYLVANIA

At Sylvania's Mountain View Laboratories, there are unlimited opportunities for the engineer who wants to work in an environment where individual contributors are recognized as the basic ingredient in creative engineering, and advancement is based on ability.

● ELECTRONIC DEFENSE LAB

Research, Development and Fabrication of electronic countermeasure systems and equipment.

SYSTEMS ENGINEERS—With special interest in advanced systems planning for electronic countermeasures systems, systems analysis, experimental and theoretical susceptibility studies, aerodynamics applied to problems by use of analog computer simulation, applied statistics involving decision, theoretic techniques, laboratory test and integration of electronic systems. Academic work beyond bachelor degree or research experience in experimental physics, statistics or electronics desirable.

ANTENNA ENGINEERS—Research, development and design of electronic countermeasures antenna systems. Requires BS/EE or physics, plus 1 year graduate study in electromagnetic theory, optics and advanced math; industrial experience, knowledge of propagation theory and capability for systems analysis. Also opportunities for recent graduates with academic background in antennas and microwaves.

ELECTRONIC ENGINEERS—Research and advanced development in the fields of electronic countermeasures and electronic systems; particular areas of activity are transmitters, receivers, analyzers, direction finders, data handling, RF circuits and antennas. Experience and/or advanced academic training are especially desirable.

MECHANICAL DESIGN ENGINEERS—Electromechanical design experience, preferably in microwave systems, equipment and packaging. Ability to originate and direct design, to follow through projects. Also engineering experience on high performance precision hydraulic drive and servo control, as in large antenna pedestals. Requires proven creative ability.

● RECONNAISSANCE SYSTEMS LAB

SYSTEMS SPECIALISTS—To apply background in engineering and basic sciences to formulating, analyzing and establishing new reconnaissance systems and systems techniques.

DEVELOPMENT ENGINEERS—To perform circuit and equipment design and development in the areas of direction finding, data handling, passive detection, receivers, RF circuits and antennas.

MICROWAVE ENGINEERS—To perform theoretical and experimental work pertaining to applications of electromagnetic theory. These will include radio wave propagation studies and the design and preliminary development of microwave circuits, components and antennas.

● MICROWAVE TUBE LAB

TUBE ENGINEERS—Design, construct and test microwave tubes and perform tube redesign to meet requirements. Minimum 1 year in traveling wave tube engineering plus other tube experience.

SR. MECHANICAL ENGINEERS—To perform mechanical design on tubes, components and tooling including heat transfer, environment requirements, test procedures, write up and test evaluation. Minimum 4 years design work experience with vacuum tubes and microwave plumbing desirable.

APPLICATIONS ENGINEERS — Responsible for preparation and coordination of specifications and test procedures and evaluating developmental microwave devices. Minimum 3 years experience in electronics and microwave instrumentation. Tube experience desirable.

● MICROWAVE PHYSICS LAB

Limited openings for Specialists.
Gaseous Electronics and Microwave Ferrites.
Ph.D. desirable.

LOS ANGELES INTERVIEWS DURING WESCON
(August 19-20-21-22) Phone on these dates to arrange appointment)
MR. R. R. KEEFFE, MAdison 9-1933
or send your resume now to Mr. J. C. Richards

SYLVANIA
SYLVANIA ELECTRIC PRODUCTS INC.
P.O. Box 1296 Mountain View, California

Satisfaction: THE FOURTH DIMENSION

PHYSICISTS
and
ENGINEERS
● ELECTRONICS ● AERONAUTICAL ● MECHANICAL

of high caliber are invited to

. . . join our staff of 800 employees. A staff famous for Outstanding Contributions and Leadership in the development of high performance control systems — using an ultimate combination of gyroscopic devices, servo-mechanisms and electronic components.

. . . receive liberal starting salaries, reviews with merit adjustments and promotional increases, excellent pension plan, free-life insurance, Blue Cross-Blue Shield, 10 paid holidays and many others.

. . . work with our nucleus of accomplished Engineers and Scientists in Advanced Research and Development of INERTIAL GUIDANCE SYSTEMS, GYROSCOPIC DEVICES, SERVOMECHANISMS, ANALOGUE AND DIGITAL COMPUTERS, TRANSISTOR CIRCUITRY & OPTICAL INSTRUMENTATION.

write: *MR. I. R. SAMUELS*
director of personnel

MASSACHUSETTS
INSTITUTE OF
TECHNOLOGY
INSTRUMENTATION
LABORATORY
68 Albany Street
Cambridge 39, Massachusetts

GRADUATE COURSES may be taken for credit while earning full pay . . .

COMPUTER
ENGINEERS

Several Computer Engineers are required to service a large scale, parallel mode, binary digital computer with buffered magnetic tape input-output. Applicants must have above average understanding of electronic circuits and a Bachelor's degree in Electrical Engineering or equivalent practice experience. This is a permanent position with a leading research center and offers a challenging opportunity to qualified personnel. Receive an excellent salary and outstanding employee benefits, and enjoy stimulating staff associations.

If you possess an exceptional background in the area described, send a complete resume to:

A. J. Paneral

ARMOUR
RESEARCH FOUNDATION
of Illinois Institute of Technology
10 West 35th St. Chicago 16, Illinois

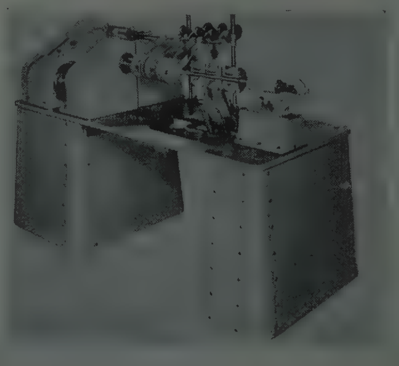
NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 24A)

Multiple Deflection Yoke Winder

A new high production deflection yoke winder featuring a newly designed rugged mechanism which assures long life and trouble-free operation is offered by **Geo. Stevens Mfg. Co., Inc.,** Pulaski Road at Peterson, Chicago 46, Ill. Model DY winds six 70, 90 and 110° yokes simultaneously and also winds color and military type deflection yokes and similar complicated shapes. A single pressing operation is required to bring coil to final shape. Virtually eliminated are rejects due to insulation fractures during pressing operations by form winding. Unique oscillating winding motion places wire in exact position on winding form to produce repetitively accurate windings. Parallel lay of wire provides greater uniformity yoke to yoke, definitely reducing convergence problem normally encountered in controlling multiple beam deflection systems such as 3-gun color tubes. Winding speed up to 320 turns per minute on 70, 90 and 110° yokes and up to 180 turns per minute on color yokes. New self-resetting time saving automatic counter requires no handling or resetting until turns count is changed. Complete job changeover takes 10 minutes. Internal mechanism is oil bath lubricated with visual gauge showing oil level at all times. Furnished with 6 tensions and take-up arms, 1 hp variable speed 230 volt 60 cps 3-phase motor, positive stopping magnetic brake, counter and heavy duty positive locking tailstock.

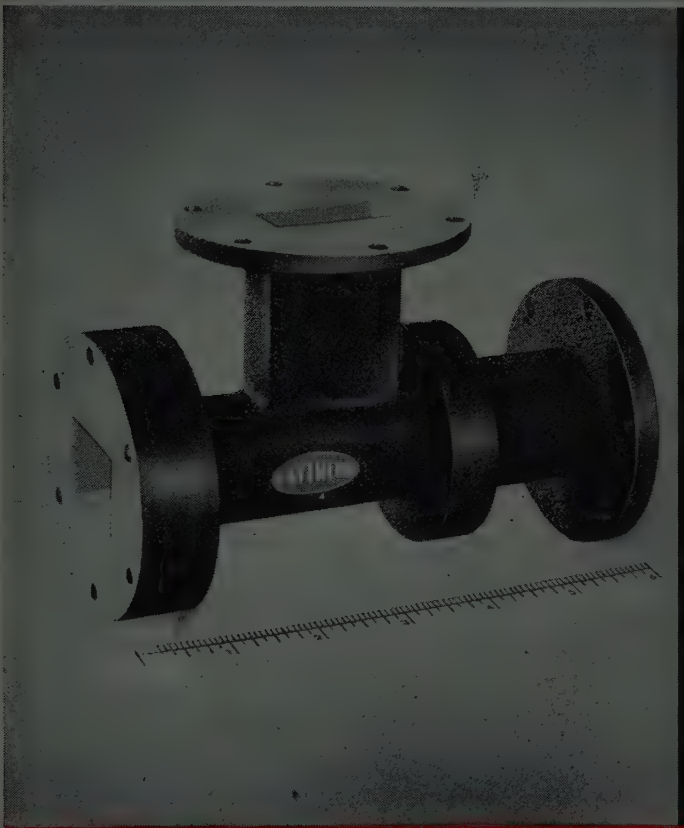


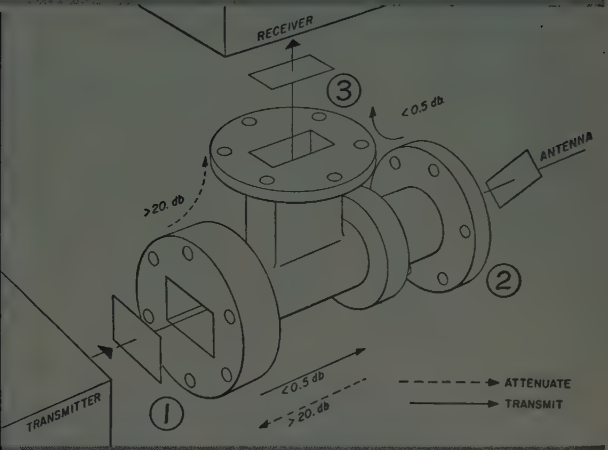
New Printed Circuit Techniques

Northeast Circuit Labs Corp., Wilmington, Mass., has recently completed a series of extensive tests on etching techniques in printed circuits. Through actual operation and cooperation with many companies this firm, with 32 years' experience in metal etching and engraving, has applied their techniques to printed circuits.

(Continued on page 130A)

Recent Raytheon achievements in Microwave





THE MICROWAVE CIRCULATOR. Typical of recent Raytheon developments in advanced microwave equipment and components is the microwave ferrite circulator recently developed by Raytheon's Special Microwave Device Group. **HOW IT WORKS:** in the diagram above, transmitted signals enter arm (1) vertically polarized. They are then rotated 45° from the vertical in a ferrite Faraday rotator with a longitudinal field applied by a small cylindrical permanent magnet. They flow out of the circulator at the antenna arm (2) which is set at the same 45° angle. Received signals fed into the antenna arm are rotated an additional 45° by the ferrite Faraday rotator and can only leave through the receiver arm (3).

To the man who is looking for
FRONTIER PROJECTS IN ELECTRONICS:

As an engineer or scientist who wants to accomplish more in 1958, you naturally want to be where new things are happening.

Whatever your specialized background and interests, chances are you'll find a current Raytheon project that offers exceptional opportunity for you to put your scientific skill and creative imagination to work.

Raytheon's constant expansion during 1958 covers advanced activities in:

COMMUNICATIONS (Commercial and Military)—scatter, microwave relay, multiplex, mobile transistorized equipment.

COUNTERMEASURES—radar countermeasures equipment, advanced study projects.

RADAR (Pulse and CW Systems)—search, fire control, bombing, navigation and guidance, air-traffic control, weather and marine, military and commercial.

MARINE EQUIPMENT—submarine, ship and airborne sonar, depth sounders, direction finders, radars.

GUIDED MISSILES—prime contracts:
Navy Sparrow III (air-to-air)
Army Hawk (ground-to-air)

MICROWAVE TUBES—"Amplitrons," magnetrons, klystrons, traveling wave tubes, storage tubes, backward wave devices.

SEMICONDUCTORS—devices, materials and techniques; silicon and germanium.

• • •

For interview and prompt helpful counsel, please write to
E. H. Herlin, Professional Personnel Section
P.O. Box 237, Brighton Station, Boston 35, Mass.

Excellence in Electronics

RAYTHEON

RAYTHEON MANUFACTURING COMPANY

ENGINEERS

NOW—CHOOSE YOUR ASSIGNMENT
AND LOCATION THROUGH OUR
NATION-WIDE PLACEMENT SERVICE
SALARIES $7,500 TO $18,000

We can offer you a large selection of diversified positions with America's foremost electronic organizations WITH NO COST TO YOU.

SOME POSITIONS FOR NON-CITIZENS

WHAT WE DO FOR YOU—

Take all the work from you—no need for you to write to five or six companies, fill out applications for each one, only to find there is no job that interests you. We do all that for you, find the job that you want, in the location you want—we work with over 250 companies all over the country.

ALL WE ASK YOU TO DO—

Send us 3 complete resumes, telling us your present and desired salary; the kind of work you want and where you would like to live. That is all you have to do!

THEN YOU—

Wait to hear from us or our clients. There is *no need* to write directly to any companies, as we do all that for you and at absolutely NO COST TO YOU!

Just indicate where you would like to relocate and what you would like to do. We handle everything for you without cost or obligation.

LOCATION DESIRED

☐ New England
☐ Northern East Coast
☐ Southern East Coast
☐ Midwest
☐ Southwest
☐ West Coast

POSITION DESIRED

☐ Systems
☐ Radar
☐ Transistors
☐ Tubes
☐ TV Receivers
☐ Microwave
☐ Anal. Computers
☐ Dig. Computers
☐ Servo-Mechanisms
☐ Navigation
☐ Counter Measures
☐ Telemetering
☐ Nucleonics
☐ Ind'l. Instruments
☐ Components
☐ Circuit Design

A National Electronic Placement Service Established in 1937.
You are assured of prompt and completely confidential service by forwarding three resumes to HARRY L. BRISK, (Member IRE)

APS Accredited Personnel Service

Employment Counselors Since 1937
Department A
12 South 12th Street, Philadelphia 7, Penna. WAlnut 2-4460

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 128A)

The results of the tests in adaptation and development have been conclusively noteworthy. For instance, this firm claims to etch in production 80, 8×10, two-ounce copper boards in five minutes. 80, 8×10, eight ounce copper boards can be etched in nine minutes.

The formulas, chemicals, solutions and techniques used have been successful to the extent of eliminating 90 per cent of touch-ups.

Northeast is not a manufacturer of equipment, but of all supplies necessary to etching. However, they claim they can show any company how to construct the necessary etching equipment for under $500.

"X-C" Band Test Set

A new combination "X-C" band radar test set is now in full production at **Kearfott Company, Inc.,** Microwave Div., Van Nuys, Calif. manufacturers of precision microwave components and test equipment.

The new set will make radar system performance checks in the "X" band (8.5 kmc to 10.0 kmc) and "C" band (5.2 kmc to 5.9 kmc). Identical in function with standard "single band" models, the new unit has a unique stacking arrangement that permits the dual performance check. All four master functions for radar test equipment are incorporated into the one unit: spectrum analyzer, power monitor, signal generator, and direct reading frequency meter. Cost of the combination "X-C" band radar test set is set at $6,250.00.

Further information on the model W 909-1C-A is available on request to the firm.

15 Inch Wide Ductile Co-Netic Foil

Ductile Co-Netic magnetic shielding foil is now offered in 15 inch width by **Magnetic Shield Div., Perfection Mica Co.,** 1322 No. Elston Ave., Chicago 22, Ill. The new 15 inch width simplifies the en-

(Continued on page 132A)

follow the sun

TO PHOENIX!

...where Motorola offers rewarding opportunities!

Work where it's fun to live. Advance your career—both in recognition and financial gain—at Motorola in Phoenix.

Your *family* will share your opportunity when you settle down in sunny, dry, healthful Phoenix! Tourists spend millions of dollars every year just to visit Phoenix. The attractions of this fabulous vacationland can be yours to enjoy *year-'round* with Motorola!

EQUAL JOB For All Qualified Applicants OPPORTUNITY

If you are qualified for any of the positions below, write, wire or phone today.

ELECTRONIC ENGINEERS, MECHANICAL ENGINEERS, PHYSICISTS

System Analysis, Design and Test
Radar
Communications
Navigation
Missile Guidance
Data Processing and Display

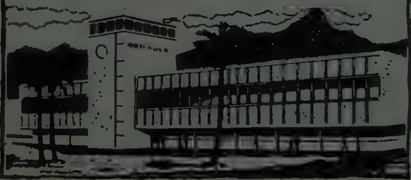
Circuit Design, Development and Packaging
Microwave
Pulse and Video
Antenna
Digital and Analog
R-F and I-F
Transistor
Servos

Technical and Specification Writing
Printed and Etched Circuitry

Write:
Mr. Kel Rowan
Western Military Electronics Center
Motorola, Inc., Dept. C-8
8201 E. McDowell Road
Phoenix, Arizona

Engineering positions also available at Motorola, Inc. in Chicago, Illinois, and Riverside, California.

MOTOROLA, INC.



BMEWS

BALLISTIC MISSILE EARLY WARNING SYSTEM

The Moorestown Engineering Plant is the home of RCA's Missile and Surface Radar Department. Within this organization lies the prime responsibility for the development, design and production of a detection system to provide early warning of missile attack on this continent. BMEWS, as it's called, requires a management and engineering effort of immense proportions. As System Project Manager, RCA Moorestown invites you to join in this effort.

RCA's Moorestown Engineering Laboratories need EE's, ME's and Physicists for . . .

• SYSTEMS ENGINEERING • DESIGN & DEVELOPMENT
• PROJECT ENGINEERING • ENGINEERING MANAGEMENT

You should have experience in one of these areas...

• Hi Power Transmitters • Receivers • Servomechanisms • Computers • Radar Antennas • Microwave Components • Pulse Circuitry • Cathode Display Devices

FOR INTERVIEW WITH ENGINEERING MANAGEMENT

Call collect or write: Mr. W. J. Henry—BElmont 5-5000
Engineering Employment, Dept. V-17H
Radio Corporation of America, Moorestown, New Jersey
Only 8 miles from Philadelphia

EQUAL JOB For All Qualified Applicants OPPORTUNITY

RCA

RADIO CORPORATION of AMERICA
MISSILE AND SURFACE RADAR DEPARTMENT

Tmk(s) ®

WE WANT MORE
HIGH LEVEL
ENGINEERS
ON OUR TEAM
at
Bendix-Pacific
in Southern California

MISSILE GUIDANCE
AIRBORNE RADAR
TELEMETERING
SONAR

There are important positions available in these small, independent engineering groups at Bendix-Pacific for high level engineers from senior grade and up. Bendix-Pacific is particularly interested in strong, analytical engineers who have the calibre and capabilities to advance into systems engineering programs.

Please write W. C. Walker your qualifications or fill in the coupon and mail it today.

**W. C. Walker, Engineering Employment Mgr.
Pacific Division, Bendix Aviation Corp.
11600 Sherman Way, North Hollywood, Calif.**

I am interested in this engineering field____
I am a graduate engineer with______degree.
I am not a graduate engineer but have ____ years experience.

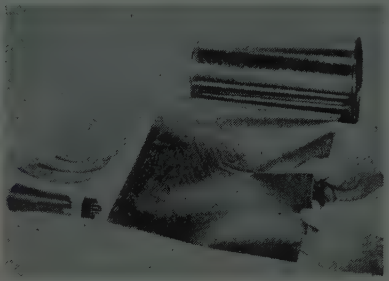
Name________________________
Address______________________
City_________________________
Zone____State_________________

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 130A)

closure of a much larger volume by minimizing the number of junctions needed when the foil was available only in 4 inch widths. The foil can be trimmed to any dimension or outline with a pair of ordinary scissors and is easily formed by hand. One or more layers can readily be applied and their effects observed, permitting the engineer to determine optimum location and number of layers necessary for adequate shielding. Co-Netic foil is non-shock sensitive, non-retentive, does not require periodic annealing and attenuates low level fields. When used with $19\frac{3}{8}$ inch wide Netic foil, the combination makes possible higher ratios of attenuation for relatively intense fields than could be attained by using the foils individually.



(Continued on page 134A)

**Perfect match!
Your ability . . .
Your future . . .
Our positions**

Make Abbott's your PERSONAL AGENT with the nation's foremost employers of engineering and scientific talent. You'll soon find your abilities being utilized right up to the maximum, with rewards and satisfactions on the same high level.

Salaries—$10,000-$20,000

ENGINEERING MANAGER—radar, computers
ENGINEERING MANAGERS—data processing
CHIEF ENGINEER—power supplies, transformers
SENIOR ENGINEER—microwave tube development
LABORATORY MANAGERS — communications
DEVELOPMENT ENGINEERS—modules, resistors, diodes
SENIOR SYSTEMS ENGINEERS — radar, guidance, computers, countermeasures
DESIGN ENGINEERS—radar, systems, circuits, components, gyros, servos, antenna

In our thirty-four years of confidential service, we have attained national recognition by leading companies as the personnel representative for engineering, scientific and administrative people. Our company clients will assume all expenses and our service charges. Please send detailed resume to Mr. George H. Sandel, Director.

ABBOTT'S
EMPLOYMENT SPECIALISTS
150 Tremont Street, Boston 11, Massachusetts

CHALLENGING OPPORTUNITIES IN RESEARCH AND DEVELOPMENT

ELECTRONIC ENGINEERS
SYSTEMS ENGINEERS

Design of electronic instrumentation for underwater ordnance. Analytical and experimental treatment of scientific research problems in the fields of hydrodynamics, acoustics, electronics, network theory, servomechanisms, mechanics, information theory and noise analysis including analogue and digital computations.

THE PENNSYLVANIA STATE UNIVERSITY
ORDNANCE RESEARCH LABORATORY
University Park, Pennsylvania

☐ Opportunities for Graduate Study
☐ Faculty Appointments for Qualified Applicants
☐ Excellent Working and Living Conditions
☐ Liberal Employee Benefit Programs

SEND RESUME TO: ARNOLD ADDISON, PERSONNEL DIRECTOR

ENGINEERS
AND
PHYSICISTS

ORLANDO • FLORIDA

A small expanding company, owned and managed by technical personnel has unusual opportunities for work in systems analysis, radar, missile guidance and space technology.

Challenging projects, attractive salary, profit sharing, investment opportunity, moving expenses paid.

Advanced degree or equivalent experience required.

SYSTEMS SI INCORPORATED
2326 DIVERSIFIED WAY • ORLANDO, FLORIDA •

ENGINEERS...

with Creative Imagination
probe physical universe
at Cubic Corporation

Cubic Engineers, endowed with creative imagination, successfully developed a single system for the simultaneous tracking or guiding of five or more anti-bomber or anti-ICBM missiles.

At Cubic Corporation creative imagination is continuing to broaden the scope and realization of such versatile systems as MOPTAR, which is completely mobile and capable of operating in the most stringent missile environments.

YOU, who enjoy the creative challenge of scientific and technical developments which probe the very nature of the physical universe, should talk to Cubic!

Cubic Corporation RIGHT NOW affords Engineers and Scientists the opportunity to grow and gain added prestige in such advanced fields as:

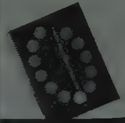
- Advanced Mathematics
- RF-UHF-VHF
- Antenna-Propagation
- Airborne Packaging
- Digital Data Handling
- Electronic Circuitry

At Cubic Corporation in beautiful, equable-climated San Diego you will be associating with a company in which creativity is required, recognized, rewarded.

Write or phone

Mr. Joseph Devlin
5575 Kearny Villa Rd.
San Diego 11, Calif.
BRowning 7-6780

Cubic
CORPORATION


follow your **career** under ideal conditions at **LIBRASCOPE**

LIBRASCOPE uses the engineering project team method.

Computer—Controls—Components
Design—Development—Manufacturing

You can be assured of ideal working conditions at well located Librascope. Why? Because of the physical plant: air-conditioned, ultra-modern; the location: at the edge of the foothills; near Los Angeles, Hollywood and the pleasant residential family areas of Burbank, Glendale, Pasadena.

A company with highest professional and technical standards. If you are an M.E. or E.E., mathematician or physicist, interested in Analog or Digital Computers • Logical Design • Instrumentation • Servo Mechanisms • Electro-mechanical • Systems • Transistor Applications • Controls for commercial and Military Equipment, you're invited to investigate the opportunities at Librascope which has just held its 20th Anniversary—a sound, stable organization growing with automation. **Write Glen Seltzer, Employment Manager.**

LIBRASCOPE

GPE GENERAL PRECISION EQUIPMENT CORPORATION

LIBRASCOPE, INCORPORATED
808 Western Ave. • Glendale, Calif.

Write today for this interesting booklet about Librascope.

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

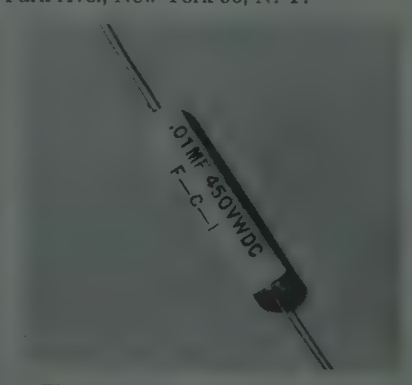
(Continued from page 132A)

20 cps-10 mc, Post-Amplifier

The new VS-102A post-amplifier designed by **Millivac Instruments, A Division of Cohu Electronics, Inc.,** has a gain of 300 a frequency response of 20 cps-10 mc and a maximum output of 28 volt peak-to-peak. Its output impedance is adjustable between 35 and 130 ohms, to match various transmission lines. It is used to increase the output voltage and output power of continuous wave generators and sweep generators, to make possible alignment of amplifier output stages at their true high operating signal level. Capacitive loads as high as 100 $\mu\mu$f have practically no influence on the output voltage of this amplifier at its upper 10 mc frequency limit.

Capacitors For Filter Network

A line of low cost capacitors for use in filter networks featuring close tolerance and high stability has been announced for immediate delivery by the **Special Products Dept., Film Capacitors, Inc.,** 3400 Park Ave., New York 56, N. Y.



The units have been designed to achieve a tolerance of 1 per cent, and a temperature coefficient as low as 100 parts per million.

(Continued on page 136A)

TUBE ENGINEERS

NEW FLORIDA ELECTRONIC TUBE PLANT OF SPERRY ELECTRONIC TUBE DIVISION

UNUSUAL OPPORTUNITIES
ON NEW PROJECTS
In The Microwave Tube Field
for RESEARCH, DEVELOPMENT
and
PRODUCTION ENGINEERS

B.S., M.S., or Ph.D's or equivalent, with previous experience or training on magnetrons, klystrons, and traveling wave tubes, etc.

Here you will find a unique, perfect combination for maximum professional development, expression and recognition...a new division, recently started production, offering exceptional growth potential...yet possessing the stability and "Know How" of Sperry's 50 year history of engineering accomplishments.

ENJOY PLEASANT
FAMILY LIVING IN FLORIDA

Our plant is located in the University City of Gainesville, Florida, noted for excellent all year round climate, unexcelled fishing, boating and swimming at nearby lake and gulf beaches, uncrowded living conditions with excellent housing available.

PLEASE SUBMIT RESUME TO
EMPLOYMENT DEPT.

SPERRY
ELECTRONIC TUBE DIVISION
of Sperry Rand Corp.
Gainesville, Florida

work in the fields of the future at NAA

ELECTRO-MECHANICAL ELECTRONIC ENGINEERS

A BS or advanced degrees in EE, ME, or Physics, may qualify you for a rewarding career at North American Aviation, in one of these fields:

Flight Control Analysis, Reliability Analysis, Flight Simulation, Systems Analysis.

Electrical Systems Analysis and Design, Mission and Traffic Control, Fire Control, Bombing Systems, Electronics Systems Integration, Flight Controls, Ground Support Equipment, Airborne and Electronic Test Equipment.

Applied Research in Radome Development, Antenna Development, Infrared, and Acoustics.

Please write to: Mr. B. H. Stevenson, Engineering Personnel, North American Aviation, Los Angeles 45, California.

THE LOS ANGELES DIVISION OF
NORTH AMERICAN AVIATION, INC.

Engineers & Scientists
OPPORTUNITIES IN

ecm

at melpar

For every new weapon devised a countermeasure has followed to balance the scale.

At Melpar a major segment of our effort is directed toward developing electronic countermeasures to offset the anticipated weapons of tomorrow.

The experienced engineer with an interest in ECM will find Melpar can offer not only the technical challenge he is seeking but also advancement opportunities necessary to further his career.

Our modern and well-equipped laboratories are located in choice suburban areas near Washington, D. C. and Boston, Massachusetts. These locales were selected because of their proximity to superior educational, cultural and recreational facilities. Fine housing in all price ranges is readily available.

For detailed information about openings, write to:
Technical Personnel Representative

MELPAR *Incorporated*
A Subsidiary of Westinghouse Air Brake Company
3110 Arlington Boulevard, Falls Church, Virginia
10 miles from Washington, D.C.

ENGINEERS
for Development of
ADVANCED CELESTIAL NAVIGATION SYSTEMS

PROJECT & STAFF POSITIONS
Available to those interested and qualified for serious development work in:

Airborne Navigation Systems
Related Electronics
Analog & Digital Computers
Associated Test Equipment

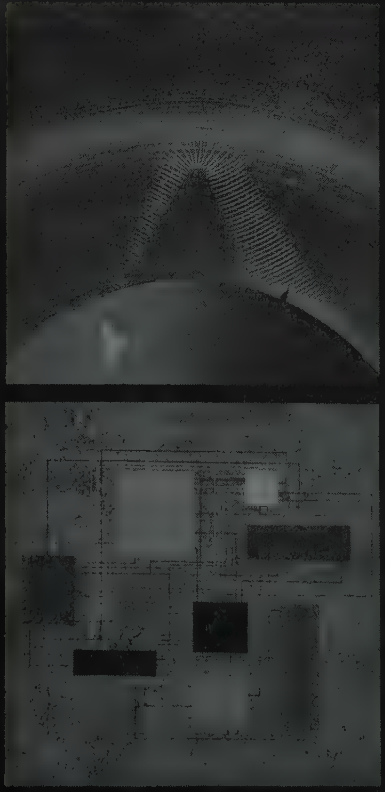
Minimum 4 years experience in military navigation-type servos, computers, electronics, photoelectric tracking or other related equipment desired.

FIELD ENGINEERS
for Development and Flight Evaluation Work

ENGINEERS
BS or EE degree. Experienced in servo motor or rate generator design.

For further information about positions available with Kollsman, designers of America's finest aircraft instruments, send a resume to T. A. DeLuca.

kollsman INSTRUMENT CORPORATION
80-08 45th AVENUE, ELMHURST, NEW YORK • SUBSIDIARY OF Standard COIL PRODUCTS CO. INC.



COMMUNICATIONS and RECONNAISSANCE SYSTEMS ENGINEERING

New programs at The Ramo-Wooldridge Corporation have created unusual opportunities for electronic engineers and scientists in systems engineering. The work will include system synthesis and analysis, and the development and application of advanced techniques.

Candidates should hold advanced degrees in E.E. or Physics, and have experience in operations analysis, systems analysis, or systems engineering.

Inquiries should be addressed to Mr. C. J. Breuer.

THE RAMO-WOOLDRIDGE CORPORATION • P.O. BOX 45444, AIRPORT STATION
LOS ANGELES 45, CALIFORNIA

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

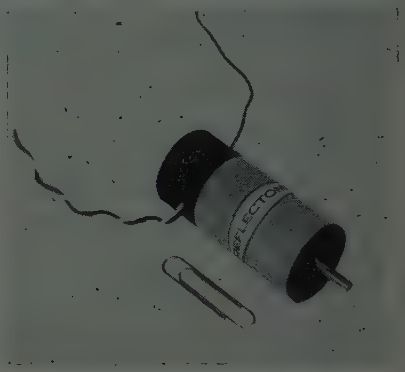
(Continued from page 134A)

To meet the basic network requirements of small size, the FCI filter network capacitors have been miniaturized.

For maximum flexibility, the capacitors are available in polystyrene, mylar, and silicone-paper dielectric.

Permanent Magnet Motors

A new line of dc permanent magnet motors has been announced by **The Reflectone Corp.,** Stamford, Conn. Offering efficiencies as high as 45 per cent, they feature a unique integral construction to reduce length and bulk, and utilize the latest developments in ceramic magnetics.



Available in stock models from 4 to 30 vdc, the motors have a wide variety of commercial and military applications, including timers, high-speed blowers and all types of portable equipment such as movie cameras, dictation machines and tape recorders.

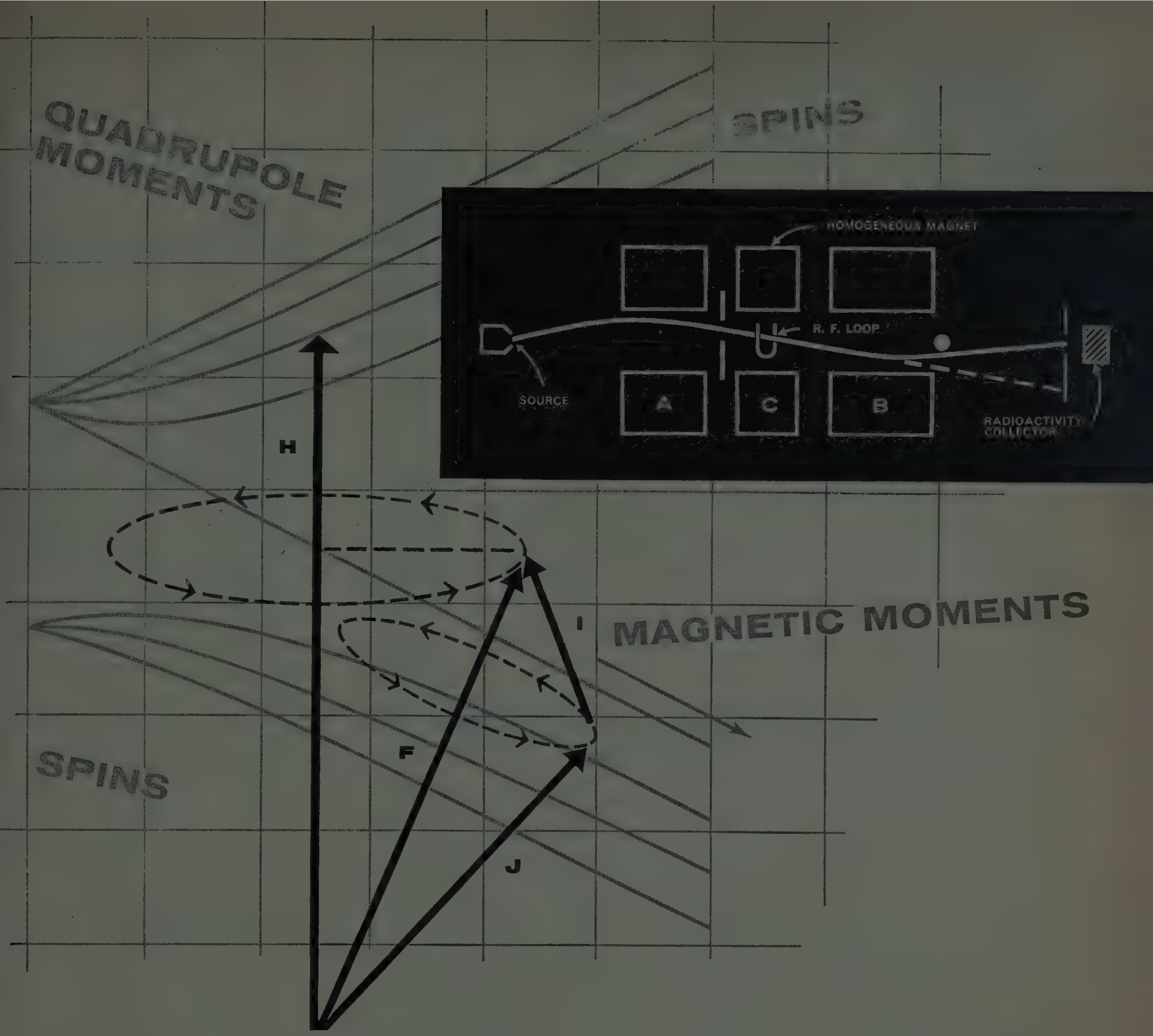
Assembly is compact, simple and rugged. The Indox I field structure is totally enclosed within a steel shell, providing complete self-shielding, and the assembly is readily mounted or dismounted without affecting magnetic characteristics.

This motor is available in sleeve bearing or ball bearing with a variety of shaft extensions or mounting arrangements. It is also available as a gear motor in various speed reductions. All combinations are available with a governor for constant speed.

X-Y Recorder

The Model 6 Autograf, manufactured by **F. L. Moseley Co.,** 409 N. Fair Oaks Ave., Pasadena 3, Calif., is an X-Y recorder of the "Automatic Chart Advance" type. Electrically it is similar to the Model 4 Autograf, and like the Model 4, is designed for rack mounting. Completely self contained, the Model 6 provides facilities for curve drawing, curve following, and point plotting from two variables in almost any application where data can be reduced to electrical form. With available acces-

(Continued on page 138A)


QUADRUPOLE MOMENTS
SPINS
HOMOGENEOUS MAGNET
R. F. LOOP
SOURCE
A
C
B
RADIOACTIVITY COLLECTOR
H
I
MAGNETIC MOMENTS
F
SPINS
J

MEASURING NUCLEAR PROPERTIES BY MOLECULAR BEAM TECHNIQUES

Nuclear theories are in the realm of idle speculation unless physicists are given the opportunity to compare the predicted results with experiment. Molecular beam techniques are one of the methods used at Argonne for investigating the properties of radioactive nuclei. These provide tests for present theory and guideposts for the future.

Staff Positions Available For Qualified:

PHYSICISTS • CHEMISTS • PHYSICAL METALLURGISTS • CHEMICAL ENGINEERS • METALLURGICAL ENGINEERS • MECHANICAL ENGINEERS • ELECTRICAL ENGINEERS • TECHNICAL WRITERS

Argonne
NATIONAL LABORATORY

Operated by the University of Chicago under
contract with the United States Atomic Energy Commission.
PROFESSIONAL PERSONNEL OFFICE
P.O. BOX 299-C4 • LEMONT, ILLINOIS

ELECTRONICS ENGINEERS
and PHYSICISTS

Aeronutronic is expanding military and commercial programs involving the most advanced research, development, experimentation and prototype production at plants in Glendale and at modern, new facilities overlooking the Pacific Ocean at Newport Beach, California.

Career opportunities are open for scientists and engineers of high calibre in the fields of space technology, range instrumentation, missiles electronics, automatic controls, and display systems. Advanced degree and three to five years' experience in telemetry, radio propagation, atmospheric physics, servomechanisms, electronic and/or mechanical design, or plasma physics desirable. U.S. citizenship necessary. Qualified applicants are invited to send resume to Mr. L. R. Stapel.

AERONUTRONIC SYSTEMS, INC.
a subsidiary of Ford Motor Company
1234 Air Way, Bldg. 29, Glendale, California • CHapman 5-6651

MICROWAVE
TUBE
ENGINEERS

An expanding program of vital military and commercial developments has created new openings for qualified engineers and scientists interested in microwave tube research, development, design and application.

If you are interested in growth opportunities and have experience in the field of microwave beam devices such as klystrons and traveling wave tubes, microwave components and related technology, you are invited to write Professional Personnel Director, Division 48

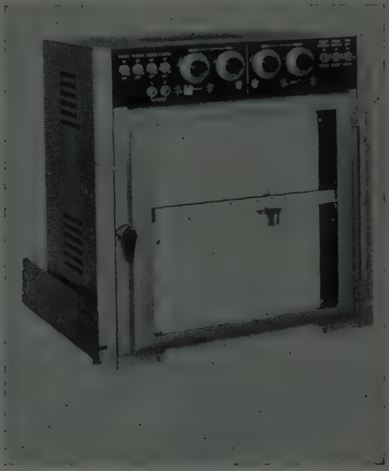
GENERAL ELECTRIC

MICROWAVE LABORATORY
601 CALIFORNIA AVENUE
PALO ALTO • CALIFORNIA

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 136A)

sories it may be used for punched card reading, automatic gain-frequency curve drawing, perforated tape reading, and so forth.



A feature of the Model 6 is its chart advance mechanism. This model is designed to accept a roll of up to 100 complete charts which may be advanced into place one at a time by manual or automatic means. Thus a series of complete single charts may be recorded and stored on a single roll, obviating the annoyance of placement of new charts on the recording surface at frequent intervals. A built-in vacuum system holds the paper firmly in place during the recording process. Independent servo-actuated drives, electrically isolated from ground, drive a removable ink pen to provide smooth recordings from filtered input circuits.

Model 6 Autograf X-Y recorder (automatic chart advance type): Paper size: roll chart type; provides 10 inches calibrated recording width in X direction and 10 inches in Y direction. Recording speed: various speeds available depending on application requirements. Maximum speed ½ second on Y axis; 1 second on X. Input Voltages Ranges: 5 millivolts to 500 volts, dc, each axis. Special scales and ranges available. Input resistance: 200,000 ohms per volt up to 10 volt range; 2 megohms on all higher ranges. Accuracy: Better than 0.25 per cent of full scale; Resetability better than 0.1 per cent of full scale.

3-Axis Simulators

J. W. Fecker, Inc., 6592 Hamilton Ave., Pittsburgh, Pa., subsidiary of **American Optical Co.,** has introduced 3-axis flight simulators for testing the mechanical and electronic inertial guidance assemblies and components of missiles and aircraft. The units can also be used to test gyroscopes and the electronic and mechanical navigational equipment of naval vessels.

(Continued on page 140A)

ELECTRONIC ENGINEERS

needed at

MARTIN

New long-term developments at Martin in the field of electronics have created exceptional opportunities for top electronic engineers. At least 5 years experience required. Salaries from $9,000 to $15,000.

Openings in these areas:

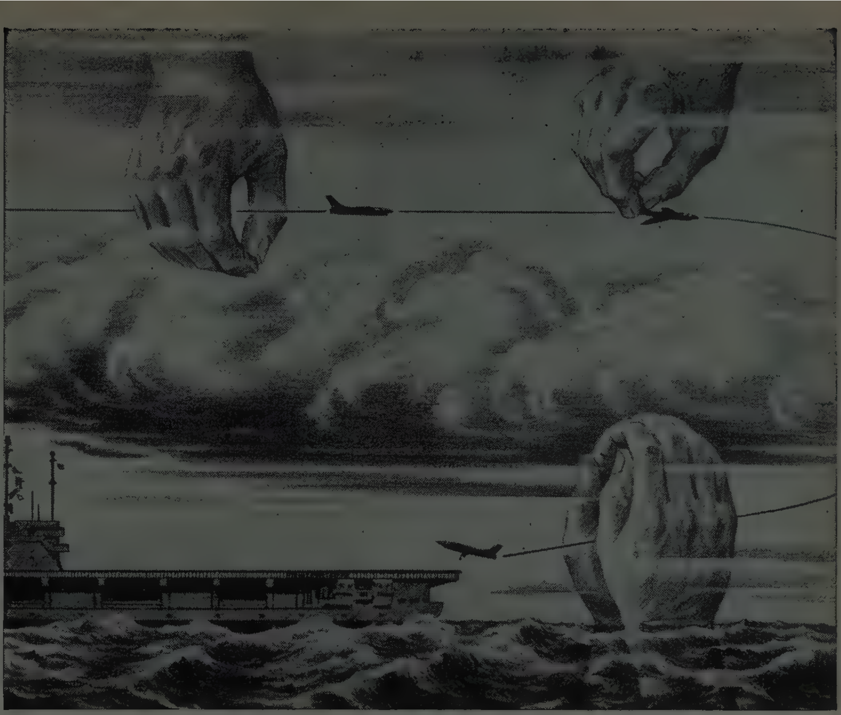
- Circuit Design
- Systems
- Inertial Guidance
- Countermeasures
- Digital Computers
- Test Equipment Design

WRITE TO:

William Spangler, Manager
Professional Employment
Department P-8
The Martin Company
Baltimore 3, Md.

MARTIN

BALTIMORE



Cornell Aeronautical Laboratory and . . .

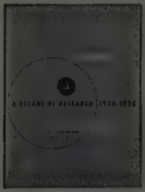
ALL-WEATHER RETURN-TO-CARRIER FLIGHT

A hundred jet aircraft scream toward their distant carrier. Some are disabled; others, critically low on fuel. Their landing must be swift; timed to the second. This systems problem was assigned to Cornell Aeronautical Laboratory scientists and engineers by the Bureau of Ships seven years ago. Project name: PACO—Problems of All-Weather Carrier Operations.

In order to link the carrier to the flight group beyond the horizon . . . establish mutually compatible flight paths . . . control an efficient landing sequence (with provision for emergency landings and wave-offs) . . . and to land the planes automatically on an unstable deck, electronics in every conceivable form has been focused on the problem.

Systems engineering, traffic control philosophy and the inter-relation of aerodynamics and electronics all play a part in the systems design and experimental support work of C.A.L.'s project team. Their efforts have resulted in significant contributions to equipment development including TACAN, Data Link and Traffic Control Computer, Transition and Wave-Off Computer, and Automatic Landing System with Deck Motion Predictor.

PACO typifies the broad scope and professional maturity of research projects at C.A.L. If you are interested in becoming a member of one of our small, closely-knit research teams, write today for the factual, well illustrated, 68-page report entitled, "A Decade of Research." Mail the coupon now for your free copy.



FREE REPORT

CORNELL AERONAUTICAL LABORATORY, INC.
OF CORNELL UNIVERSITY

J. P. RUCH RTC
CORNELL AERONAUTICAL LABORATORY, INC.
Buffalo 21, New York

Please send me a copy of "A Decade of Research."

Name ____________________
Street ____________________
City ____________ Zone ______ State ______

☐ Please include employment information

SENIOR

ASSOCIATE

POSITIONS

Physicist—E. E.—
Mathematician with established
reputation and experience

1.
Supervision of research program in advanced passive-active detection systems, using advanced radar and passive detection techniques

2.
Supervision of a research program in large, real-time digital computer and control systems, including programming, input-output, and functional organization.

Initial salary $18,000 to $22,000 commensurate with experience, plus stock option and other executive perquisites.

Opportunity in a small growing organization with a background of proven stability and notable accomplishments.

INTERESTING
SCIENTIFIC WORK
AND
REAL FINANCIAL
REWARD

G. C. DEWEY & CO., INC

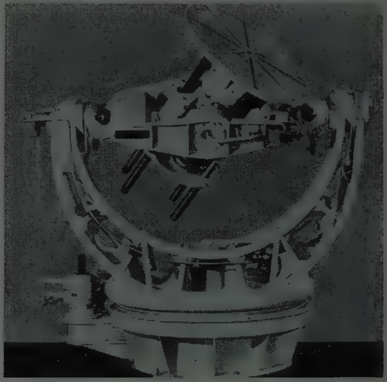
202 East 44th Street, New York 17, N.Y.

MUrray Hill 2-7369

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 138A)



These flight simulators duplicate the forces of flight or vessel motion in the three axes of yaw, pitch, and roll. Equipment under test is subject to the same rigors as actual conditions.

Speeds of up to 50 cps are possible, depending upon the variables involved. The units are hydraulically actuated and the oscillation frequency between axes is independently adjustable. They operate without appreciable resonance.

A recently built unit now in use with a major electronics equipment supplier can test packages weighing as much as 300

(Continued on page 143A)

ELECTRICAL
AND
ELECTRONIC
ENGINEERS

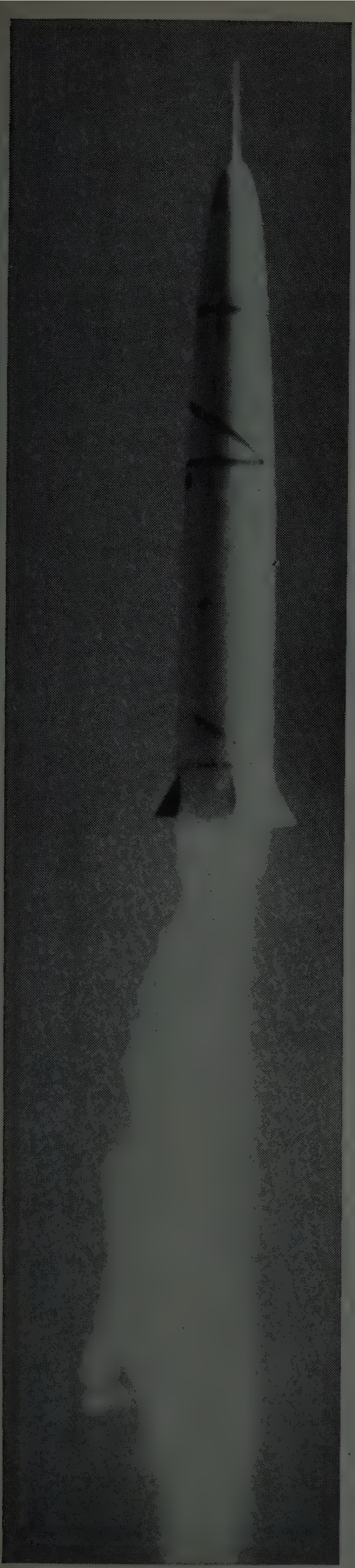
We have an exceptional opportunity for a highly creative engineer with an outstanding record of achievement and at least five years of top level experience in:

Radio—Radar Interference
Circular Wave Guide
Development

This is a permanent position, in an organization with over 20 years experience in the research and development field, offering unlimited opportunity for professional growth, stimulating staff associations and an unusually pleasant working climate, in addition to excellent salary and employee benefits.

If you are interested in a challenging research assignment, please send a complete resume to:

A. J. Paneral
ARMOUR
RESEARCH FOUNDATION
Of Illinois Institute of Technology
10 West 35th St. Chicago 16, Illinois



ENGINEERS—ELECTRONIC:
ELECTRICAL:

Air Force space and operational programs offer you unique professional challenge and opportunity as a civilian

Among the myriad current and projected programs of the U. S. Air Force lies a challenge and opportunity for civilian electronic and electrical engineers with varying degrees of specialty and experience. These areas include: the research, development and maintenance essential to sustaining qualitative superiority for the operational Air Force; research and development in IRBM and ICBM fields; the projection into outer space and return of manned, piloted vehicles. Stimulating assignments now exist for qualified men in these categories.

As an Air Force Civilian Electronic or Electrical Engineer you:

WORK... in a fine creative atmosphere... with foremost men in the field... with most modern equipment and facilities... in more than one specific program... in geographic location of your choice.

RECEIVE... assured income... low-cost life insurance... promotions from within... excellent retirement and compensation plans... protection from arbitrary separation... liberal sick and vacation leave plans.

ENJOY... expanded scope of assignment... professional prestige and recognition... job satisfaction... participation in opening new frontiers and conquering space.

For full details mail the coupon below.

Paste on Postcard and Mail or Write to:

Air Force Civilian Personnel, Dept. P2
Box 7608, Washington 4, D. C.

Please send me further information on U. S. Air Force Civilian Personnel opportunities.

Name________________________________

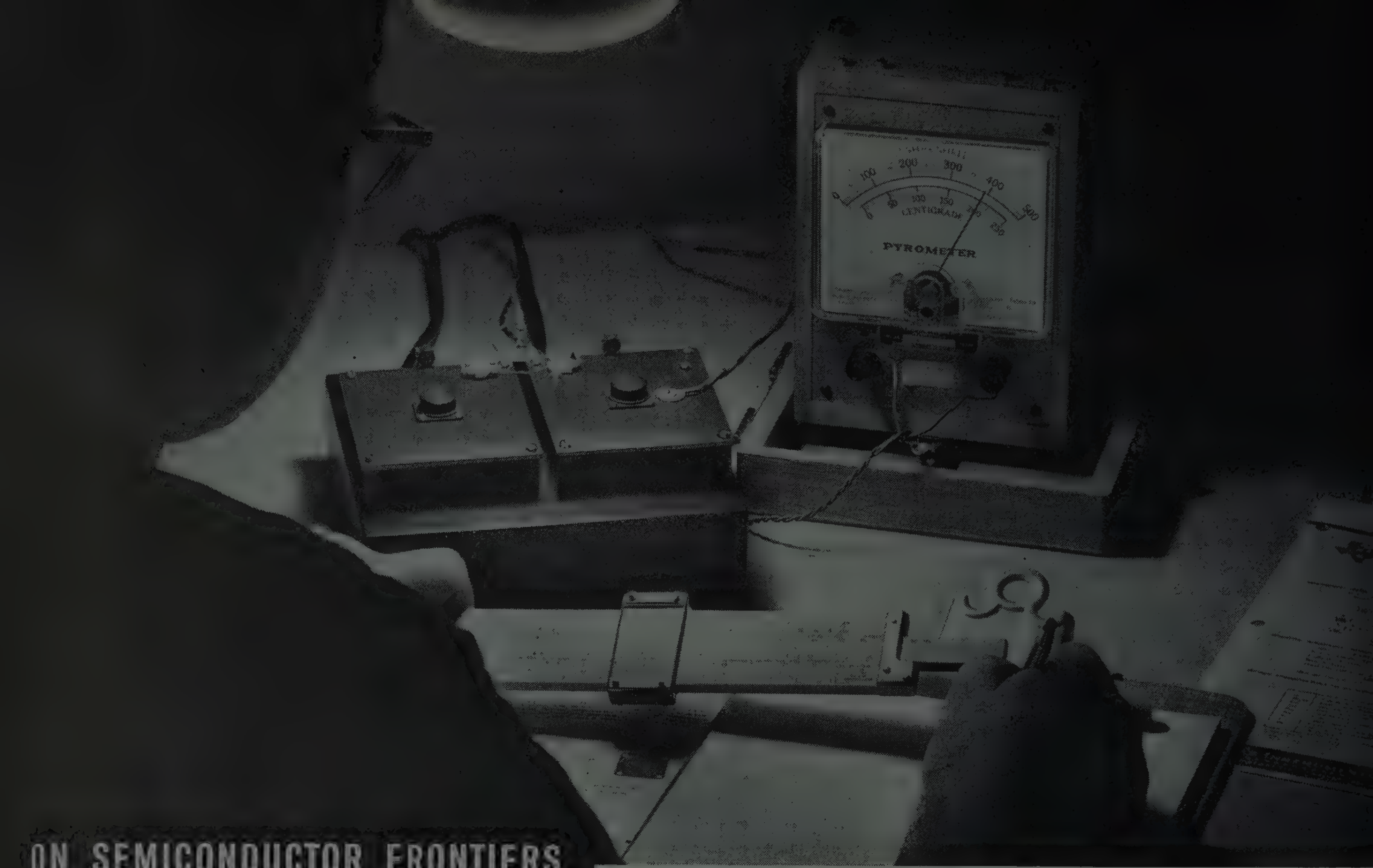
Degree(s)______________Specialty______________

Address________________________________

City______________Zone____State________

CHALLENGE
SCOPE
CREATIVITY

U.S. Air Force



ON SEMICONDUCTOR FRONTIERS

YOU can help 'beat the heat' at 200°C

ELECTRONIC ENGINEERS at TI are beating the semiconductor heat barrier with devices that will operate at 200 degrees centigrade and higher — twice the boiling point of water! Working closely with other scientists on the TI team, they continually explore new fields in electronics. Under the hot glare of infrared light which simulates extreme operating conditions, the engineer shown above is testing the newest TI silicon power transistor operating in conjunction with the totally new *Sensistor* temperature-sensing silicon resistor.

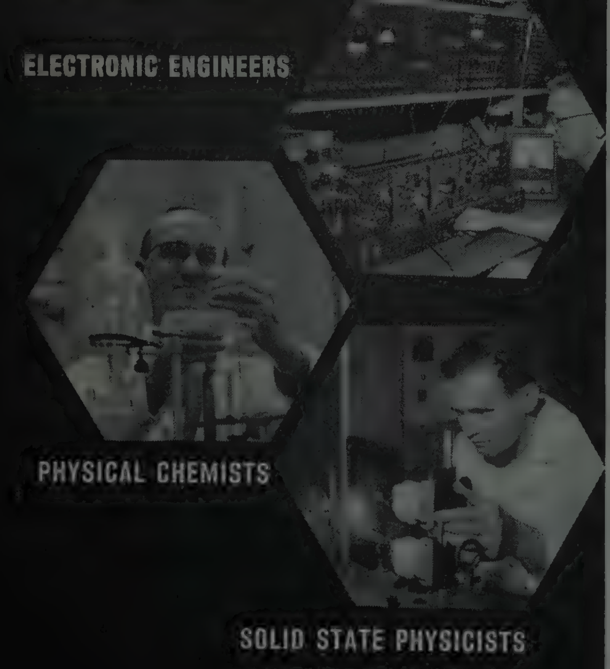
On this frontier, there is plenty of room for electronic engineers, physical chemists, solid state physicists, and others to build America's electronic future. If *you* are interested in joining other leading engineers and scientists at the industry's most modern research, development and production facilities — write or call for more information on 28-year-old Texas Instruments, recognized leader of the semiconductor industry. You will discover up-to-date supplemental benefits — profit sharing, insurance, retirement programs, and company-sponsored educational assistance.

Semiconductors and Other Components — Transistors, diodes, rectifiers, capacitors, resistors, transistor circuit applications, test equipment, mechanization. Write Harry Laur.

Electronic and Electromechanical Apparatus — Radar, sonar, infrared, optics, navigation, magnetics, telemetering, communications, computers, transformers. Write R. E. Houston.

Research and Manufacturing — PhD level for research, development and applications: solid state device technology, ferromagnetics, infrared, microwave, magnetics, digital computers, radar, sonar, telemetering, etc. Engineers for production, planning, purchasing, cost analysis, etc. Write A. E. Prescott.

TEXAS INSTRUMENTS
INCORPORATED
6000 LEMMON AVENUE • DALLAS 9, TEXAS



These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 140A)

pounds. Motion speeds can be independently varied from $\frac{1}{25}$ to 4 cps in each axis simultaneously. Variation of maximum rotational oscillation of this unit is to within ±5° at top speeds and to within ±45° at $\frac{1}{4}$ cps. Yaw axis rotational mode is 100° per second maximum under continuous rotation. Both pitch and roll axis rotation limit is ±45° maximum.

Nickel Cadmium Storage Batteries

High reliability and long life under extremes of environment are features of the improved sintered plate nickel cadmium storage batteries manufactured by **Nicad Div., Gould-National Batteries Inc.,** Easthampton, Mass.

Low internal resistance (0.001 ohms for 10 AH type cell) permits exceptionally high discharge currents. Absence of corrosive fumes is advantageous in enclosed spaces.

Illustrated are individual Nicad cells with capacities of 64, 5, 2 and 1 ampere hours. A nominal discharge of 1.2 volts per cell permits batteries to be made up in voltages a multiple of 1.2. Capacities range from $\frac{1}{2}$ to over 150 ampere hours.

Uses include portable electronic equipment, missile auxiliary power, aircraft engine starting and data processing.

Gas Purifier and Dryer

A fully automatic gas purifier and dryer, capable of operating indefinitely without attention, has been developed by the **Chemical Div., Engelhard Industries, Inc.,** 113 Astor St., Newark 2, N. J.

For use in metals, chemical, pharmaceutical, petroleum, electrical, and food processing and laboratory work, the "Deoxo* Dual Puridryer DMS" can deliver hydrogen with an oxygen content of less than one part per million and a dew point of better than −100°F, according to the firm. It also can be used with nitrogen, argon, helium, carbon dioxide, and saturated hydrocarbons.

The new device switches back and forth every 12 hours between two drying

* Reg. TM.

(Continued on page 144A)

IBM RADAR-NAVIGATION DEVELOPMENT

Outstanding opportunities for highly developed specialists in the advanced development of integrated radar-navigation systems AN/ASQ-28 for the B-70 chemical-driven bomber.

RADAR ENGINEER with a minimum of two years' experience as technical leader of radar systems development project. Duties should have included technical responsibility for major equipment and control of subcontractors' work. Further experience with transistor circuits of radar test equipment highly desirable.

INERTIAL GUIDANCE ENGINEER with a minimum of eight years' experience in servo-mechanisms or development of complex devices for military applications, including three years as technical leader of inertial guidance system development. Must have experience in astro-compass, with ability to analyze relationship of inertial equipment with bombing and navigation computer. Will assume broad project leadership in planning and controlling work of major subcontractors.

Qualifications: Bachelor's or Master's Degree in Electrical Engineering or Physics.

SYSTEMS ENGINEER with a minimum of eight years' experience in development of complex military devices in the fields of servomechanisms, radar, or computers. Able to integrate these elements in weapons systems. At least three years' experience in over-all systems analysis. Will design and analyze closed-loop systems consisting of inertial and radar equipment, display materials, and analog digital computers.

Qualifications: Bachelor's or Advanced Degree in Engineering.

COMPUTER ANALYST with one to four years' experience in digital techniques used to solve real-time control problems. Will do mathematical analyses of inertial control systems.

Qualifications: Advanced Degree in Physics or Engineering Science with strong math background.

AIRCRAFT INSTRUMENTATION SPECIALIST with flight test experience and thorough knowledge of servo-mechanisms and electronics. To work on new methods of aircraft instrumentation.

Qualifications: Master's Degree in E.E. or A.E. and four years' experience, or Ph.D. in E.E. or A.E. and background in aircraft instrumentation, especially air speed and altitude measurements.

ADVANTAGES OF IBM A recognized leader in the electronic computer field . . . products used in both military and commercial applications . . . advancement on merit . . . company-paid relocation expenses . . . liberal company benefits . . . salary commensurate with ability and experience.

Immediate openings in Owego, N.Y., in new modern engineering laboratory situated in colorful, rolling hillside of southern New York.

WRITE, outlining qualifications and experience to:

Mr. Paul E. Strohm, Dept. 645T
IBM Corporation, Owego, N. Y.

IBM
INTERNATIONAL
BUSINESS MACHINES
CORPORATION

DATA PROCESSING
ELECTRIC TYPEWRITERS
MILITARY PRODUCTS
SPECIAL ENG'G PRODUCTS
SUPPLIES
TIME EQUIPMENT

there's a
world of opportunity
for you at

AVION
acf

in advanced
R & D Programs in

INFRARED, MICROWAVE,
AIRBORNE CLOSED LOOP TV
& DATA PROCESSING

In expanding several broad research and development programs, AVION has opened several positions of unusual interest and challenge to the engineer, scientist and physicist who thrives on the creative aspects of engineering.

AVION, with a record of successes in the above fields, is led by a young, progressive management, and is backed by the stability and resources of a major, national corporation.

Positions are open at our Paramus, New Jersey, and Alexandria, Virginia, research and development laboratories, ideally located in highly desirable residential communities convenient to world-famous cultural, entertainment and shopping centers.

AVION's ADVANCED DEVELOPMENT LABORATORY

is expanding its activities in Infrared in the fields of ICBM & Satellite Detection Studies, Ground Surveillance, Missile Guidance and Detectors. This Infrared research and development work includes physics, optics, electronics, semi-conductors, systems analysis and computer studies. We are looking for research consultants, senior engineering and engineering personnel for this work.

AVION's SATELLITE PROGRAMS

which cover the field of space technology, require men with microwave systems and component engineering experience. We want research consultants, senior engineering and engineering development personnel for this expanding program.

AVION's AIRBORNE CLOSED LOOP TV

requires EE's with experience in subminiaturization and transistorization for airborne TV, to qualify as:

Project Leader
Thoroughly experienced, to take full responsibility of project groups.
Research Engineer
Knowledge of advanced TV engineering techniques as applied to airborne TV systems for research projects.
Development Engineers
EE with TV experience to work on Closed Loop TV.

AVION's DATA PROCESSING*

requires top-level engineering and scientific personnel for research and development work. Both supervisory and non-supervisory positions available. Engineering background in any ONE or a combination of the following:

—SYSTEMS DESIGN & DEVELOPMENT
—ANALYSIS & SYNTHESIS
—RESEARCH & LOGICAL DESIGN
—DIGITAL COMPUTER DESIGN

*Location: Alexandria, Va. Plant

AVION
acf

Send Resume To: Mr. Austin Pock,
Manager, Professional Employment,

AVION DIVISION
acf INDUSTRIES INCORPORATED
11 PARK PLACE, PARAMUS, NEW JERSEY   COLFAX 1-4100

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 143A)

towers containing Linde molecular sieves. While out of use, each tower is heated electrically for a short time and allowed to cool while a small flow of gas passes through it to pick up and carry off the moisture. The purging gas then is burned in a converter, so that only water vapor is expelled into the room where the instrument is installed.

In the past, manufacturers requiring a continuous gas flow had to install two units and keep an attendant on hand to reactivate the dryers.

The Puridryer is rated at 100 standard cubic feet per hour maximum. Its maximum pressure is 5 pound gauge.

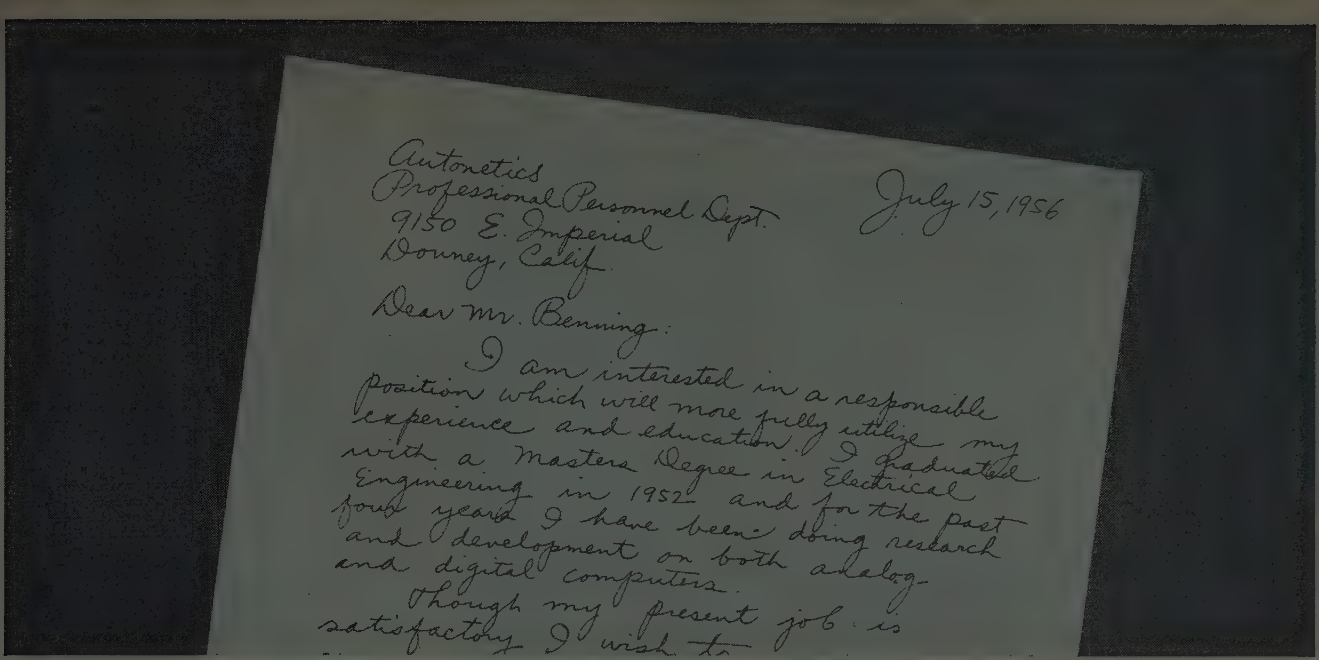
The instrument removes oxygen by catalytically combining it with hydrogen at room temperatures to form water vapor. The platinum catalyst requires no reactivation.

Automatic Voltage Regulator

A new Stabiline automatic voltage regulator type EMT4104U a product of **The Superior Electric Co.,** Dept. EMT4104U, Bristol, Conn. automatically regulates fluctuating ac power lines to maintain a constant output voltage regardless of line or load changes. The assembly is suited for applications requiring control of loads up to 35 amperes. The control location does not necessarily have to accommodate the Stabiline assembly. This type can either be used as an independent unit or as a component.

Other characteristics are zero waveform distortion; very low internal impedance; virtually zero phase shift; efficiency of better than 98 per cent; high accuracy and extreme reliability. Correction of voltage variations is accomplished in 0.1 second per volt from nominal. On nominal 120 volt, 50/60 cps service, the input voltage range is 108–137 volts and the adjustable output is 110–120 volts, 35 amperes, 4.2 kva. On nominal 240 volt service, the input range is 226–256 volts and the adjustable output is 220–240 volts, 35 amperes, 8.4 kva. For illustrated data sheet SE-L3581 write to the manufacturer.

(Continued on page 146A)



Autonetics
Professional Personnel Dept.
9150 E. Imperial
Downey, Calif.

July 15, 1956

Dear Mr. Benning:

I am interested in a responsible position which will more fully utilize my experience and education. I graduated with a Masters Degree in Electrical Engineering in 1952 and for the past four years I have been doing research and development on both analog and digital computers.

Though my present job is satisfactory I wish to

This letter moved an engineer ahead 5 years

Two years ago a man took 10 minutes to write this letter. Today he enjoys the responsibility and professional standing in the Autonetics Division of North American that might have taken 5 years to achieve elsewhere.

COMPUTERS AT AUTONETICS—A FIELD OF OPPORTUNITY

At Autonetics we have concentrated on developing original techniques in transistor circuitry, miniaturization, and quantity manufacture of precision components. For only with these new arts is it possible to create computers so small, rugged, reliable—yet so big in performance—that they can meet the demands of the space age or the increasingly complex problems of industry.

Our engineers have designed and built both analog and digital computers—for inertial navigation, bombing-navigation, armament control, flight control and data processing equipment. Out of this experience, Autonetics built the first transistorized digital computer of true general purpose capacity.

Today at Autonetics there's a respected combination of scientists, engineers, and production men constantly forging ahead into vital new technologies. Every state of the art is represented, from preliminary conception right through manufacturing. Facilities are the finest—and it's just a short jaunt to mountains, beaches or desert.

You owe it to yourself to consider how far you can advance by entering this exceptionally promising field right now. Here are the opportunities:

LOGICAL DESIGN • SMALL COMPUTER PROGRAMMING • SYSTEMS DESIGN, DEVELOPMENT AND TEST • TRANSISTOR CIRCUITRY • MAGNETIC MEMORY • SYSTEMS INTEGRATION • FIELD SERVICE ENGINEERING.

Write your letter today. Please include a resume of your qualifications. Decide now to investigate your opportunities at Autonetics. Reply will be prompt, factual, confidential.

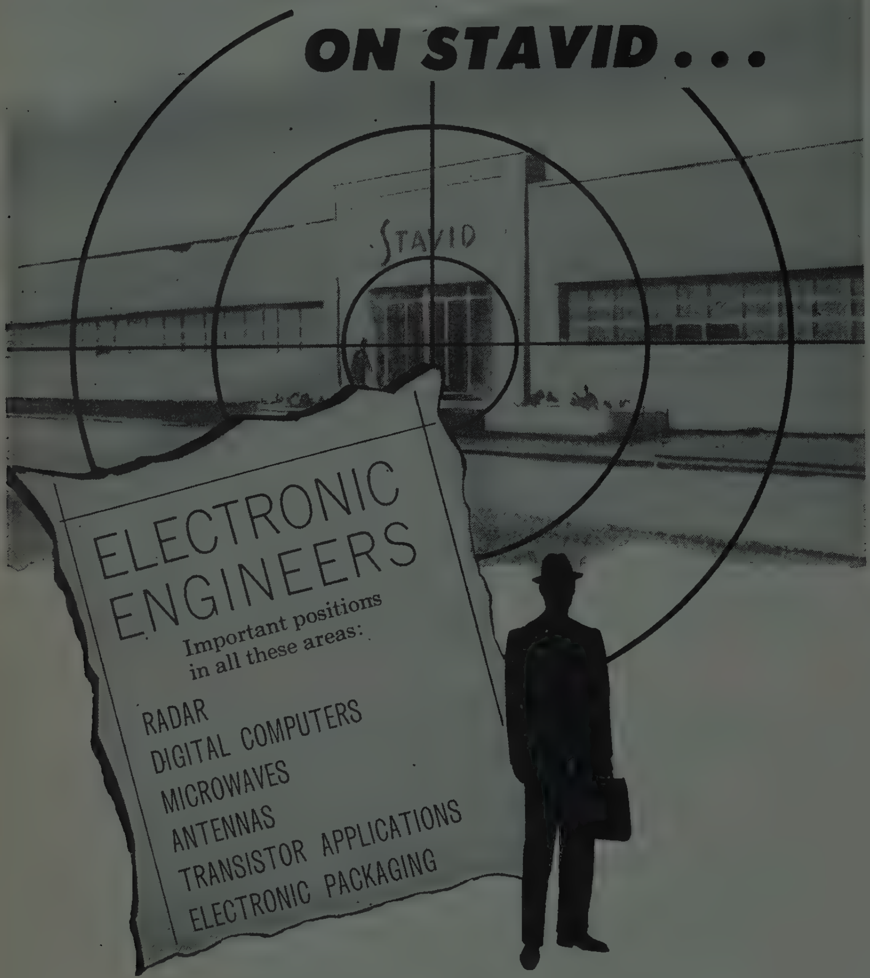
Write G. H. Benning, Manager, Employment Services.
9150 E. Imperial Highway, Downey, California

Autonetics
A DIVISION OF NORTH AMERICAN AVIATION, INC.

NERVE CENTER OF THE NEW INDUSTRIAL ERA

Engineers...

SET YOUR SIGHTS ON STAVID...



STAVID OFFERS REMARKABLE OPPORTUNITIES TO EXPERIENCED ELECTRONIC ENGINEERS IN RESEARCH • DESIGN • FIELD ENGINEERING

Stavid is a dynamic, expanding organization which has already set the pace in a number of military electronic engineering programs. Stavid offers an ideal location (45 minutes by car from New York City, only one hour from mountain and seashore vacationlands).

Investigate Stavid's extensive benefits — liberal vacation plan, extended retirement age limits, excellent pension plan and many other advantageous programs. Let us tell you about the challenges, the unusual opportunities Stavid offers; and let us show you our modern facilities — symbols of Stavid's bright future.

Call for interview, or send complete resume to
J. R. Clovis, Engineering Personnel Department.
Your inquiry will receive prompt attention and will be held in strict confidence.

STAVID Engineering, Inc.

U. S. Highway 22, Plainfield, New Jersey, PLainfield 7-1600

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 144A)

Miniature Connectors

A specially designed, environmental connector utilizing six coax contacts and thirteen #20 contacts is now offered by **The Deutsch Co.**, 7000 Avalon Blvd., Los Angeles 3, Calif., manufacturer of miniature electrical connectors.

Available in six alternate insert positions, the push-pull, quick disconnect connector features either standard or special coupling rings that lock and unlock in the

(Continued on page 148A)

Mr. Electronic Engineer

You May Have

the qualifications which could make you a vital part of our expanding R/D staff.

Your choice with one of the nation's leading electronic manufacturers in any one of these fields.

- Transistor Circuits
- SSB
- Phasor and RF Network
- High Power Transmitters
- Fatigue Amplifiers
- Electro-mechanical

Contact
N. L. Jochem, Director of Engineering
Box P-3
GATES RADIO COMPANY
Quincy, Illinois
A subsidiary of
Harris-Intertype Corporation

ENGINEERS
and
SCIENTISTS
there's genuine opportunity at General Mills

The Mechanical Division of General Mills, Minneapolis, Minnesota, needs senior level staff personnel for creative design and development in the following fields:

- **Advanced Digital Computer Systems Design**
- **Advanced Digital Computer Circuit Development**
- **Advanced Pulse and Video Circuit Development**
- **Advanced Electromechanical Computer Development**
- **Advanced Inertial Navigational System Development**
- **Optical and Infra-Red Equipment Engineering**
- **Test and Evaluation of Basic Electronic and Electromechanical Components**
- **Aerodynamicists**
- **Telemetry systems engineers**

Positions available for *purely technical* and for *technical*-supervisory work—job titles and salary provide *equal* opportunity for advancement in both.

Positions exist in Engineering Department which is engaged in advanced design and development of military weapons and reconnaissance systems, communications, controls, guidance, navigation, and special purpose digital computers. Work is mainly military, with some special commercial instrumentation and control.

If you have at least five years' experience in creative design or development—a good understanding of fundamentals and ability to apply them—learn more about the opportunity and long range security offered at General Mills. You'll like our people, our interesting, non-routine projects—and you'll like Minnesota, land of lakes and pine. In Minnesota everyone takes time to enjoy life.

Write for more facts.

MECHANICAL DIVISION General Mills

Personnel Department P 2
2003 E. Hennepin, Minneapolis 13, Minn.

MISSILES
YOUR
GOAL?
DANGER

Get into a key missile program at BENDIX —prime contractor for the Talos missile

Engineering can be a really satisfying career—and within engineering one branch stands out. That's Guided Missiles. If the missile field is the one you want—hear this. We need engineers with exceptional ability who can handle responsibility.

At Bendix you work with men who are outstanding in every phase of engineering. You use facilities second to none. You do work that's challenging and important—work that offers exceptional opportunities to build your professional standing.

You will enjoy Midwestern living at Bendix, too. Fine, four-season climate and excellent recreational facilities are close at hand. In addition, Bendix offers you a liberal personal benefit program.

If this interests you and you want additional information, mail the coupon below for your copy of "Opportunities Abound at Bendix Missiles". You can read it through in half an hour—and it may prove to be the best half hour you've ever spent in your life.

Bendix Products Division—Missiles
402P S. Beiger St., Mishawaka, Ind.

Gentlemen: I would like more information concerning opportunities in guided missiles. Please send me the booklet "Opportunities Abound at Bendix Missiles."

NAME ____________________
ADDRESS ____________________
CITY ____________ STATE ____________

ELECTRONICS ENGINEERS

with specialized experience

Senior and intermediate positions for experienced engineers are available with Curtiss-Wright, through expansion of divisional activities in these fields:

- Analog Computers and servo-mechanisms
- Digital Computers — General Purpose and Real Time
  - (a) Logical Design
  - (b) Circuits and Systems
- Missile Guidance
- Airborne Navigation and Communication
- Radar System — Pulse Circuits
- Weapons Systems

Salaries are commensurate with your abilities and experience. In addition, liberal employee benefits are part of the program of this diversified organization where individual accomplishments are quickly recognized. Positions are open, although not all in each category, at the following Curtiss-Wright Divisions: Electronics Division, Carlstadt, N.J.; Research Division, Quehanna, Pennsylvania (40 miles north of State College — Pennsylvania State University); Aerophysics Development Corporation, Santa Barbara, California and Utica Division, Utica, Michigan.

Send detailed resume including salary requirements to:
T. W. COZINE
Mgr., Engineering Recruitment,
Dept. G-11,
Curtiss-Wright Corporation,
Wood-Ridge, N. J.

All replies confidential

CURTISS-WRIGHT
CORPORATION • WOOD-RIDGE, N. J.

ENGINEERS

Positions available at Sanders Associates, Inc., a company organized, owned and run BY *engineers,* FOR *engineers, in the beautiful New Hampshire hill country less than an hour from downtown Boston.*

Please send resume to D. H. Johnson.

SYSTEMS
STUDY, ANALYSIS & ADVANCED DEVELOPMENT

Radar
Microwave Antennas
Navigational Guidance
Electromechanical Controls
Electronic Countermeasures

PRODUCT DESIGN & DEVELOPMENT

Rate Gyroscopes
Receiver Packages
Hydraulic Servo Valves
Photo-Etched Microwave Components

SANDERS ASSOCIATES INCORPORATED

95 Canal St.
Nashua, New Hampshire

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

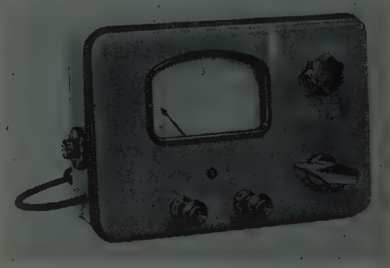
(Continued from page 146A)

direction of plug travel without lockwiring or twisting, without bayonet or coupling-nut.

Coax contacts will accept RG-196/U cable. Pins or sockets are available in either the plug or the receptacle. Dimensions on the receptacle are $1\frac{25}{64}$ in length and $1\frac{1}{2}$ inches in diameter. Plug dimensions are $1\frac{27}{64}$ in length and $1\frac{1}{2}$ inches in diameter.

Full information on this connector with coax contacts can be obtained by writing to the firm.

Ohmmeter for Transistor Circuitry



The Model 321 is claimed to be the first direct-reading ohmmeter usable safely in all transistor circuitry. This new unit, a product of **Electronic Applications,** 194 Richmond Hill Ave., Stamford, Conn., features absolute minimum of loading (under 30 mv to 300 ohms), wide range from 10 milliohms to 10 megohms in 8 ranges, 2 per cent accuracy. Size is $8\frac{1}{2} \times 6 \times 4\frac{1}{2}$ inches.

Write to the firm for literature and prices.

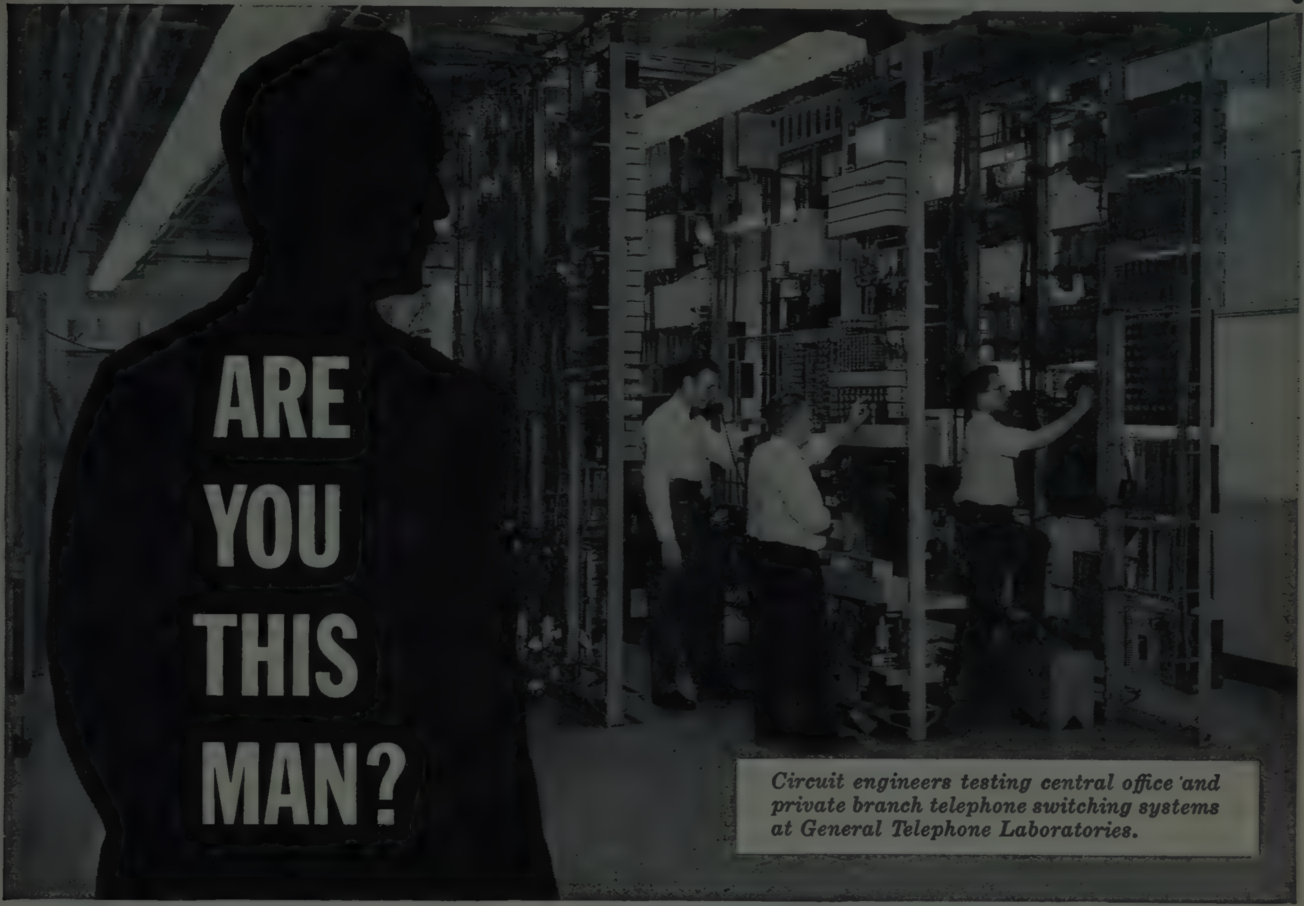
Subminiature Switch

A new "Q" subminiature switch, no bigger than a ten cent piece, which carries a 10 ampere 115 volt capacity was announced by **Acro Div., Robertshaw-Fulton Controls Co.,** Columbus 16, Ohio.

The new snap-action subminiature switch has an unusual circular design, making it adaptable to space-conserving

(Continued on page 150A)

The GENERAL Idea on Engineering Careers



Circuit engineers testing central office and private branch telephone switching systems at General Telephone Laboratories.

IF YOU are a man who has kept pace with the fast-moving art of telephony—and are qualified as a senior engineer—we have a challenging assignment for you at General Telephone Laboratories.

For example, working on the complex circuitry and high-speed switching involved in direct distance dialing. Not all of the problems have been solved. There's a big field for new ideas to meet the challenge of this latest marvel.

We're investigating new detection methods—striving constantly for systems that will do more, and will do it faster and with increased reliability.

But research and development in communications is only one phase of our work at General Telephone Laboratories. We also provide R & D support for our manufacturing affiliate, Automatic Electric, whose pioneering in automatic telephony was the forerunner of automated equipment so widely used throughout industry today.

We work in close cooperation with thousands of telephone companies in the U. S. and abroad—including the operating and manufacturing companies of General Telephone—*America's second largest and fastest-growing telephone system!*

• •

Grow with us—The tremendous growth of communications—and the wide application of automation principles—have created many new engineering opportunities here at General Telephone Laboratories. We have a challenging opening for you if you are qualified for senior research and development work in electrical, electromechanical or mechanical engineering, electronics, or physics. We can be more specific about your particular opportunity if you will write in confidence to Mr. Robert Wopat, President, General Telephone Laboratories, Northlake, Illinois.

GENERAL TELEPHONE LABORATORIES

To the talented engineer and scientist

APL OFFERS GREATER FREEDOM OF ACTIVITY

APL has responsibility for the *technical direction* of much of the guided missile program of the Navy Bureau of Ordnance. As a result staff members participate in assignments of challenging scope that range from basic research to prototype testing of weapons and weapons systems.

A high degree of freedom of action enables APL staff members to give free rein to their talents and ideas. Thus, professional advancement and opportunities to accept program responsibility come rapidly. Promotion is rapid, too, because of our policy of placing professional technical men at all levels of supervision.

APL's past accomplishments include: the first ramjet engine, the Aerobee high altitude rocket, the supersonic Terrier, Tartar, and Talos missiles. Presently the Laboratory is engaged in solving complex and advanced problems leading to future weapons and weapons systems vital to the national security. Interested engineers and physicists are invited to address inquiries to:

Professional Staff Appointments

The Johns Hopkins University
Applied Physics Laboratory

8603 Georgia Avenue, Silver Spring, Maryland

(Continued from page 148A)

applications. Uses for the switch have been found in vending devices, electronic equipment, appliances, business machines, automotive products and communications equipment, according to the company.

Results of a market survey conducted by the controls manufacturer indicate the price of the "Q" switch is one half of comparable models.

The device is available with a tiny panel mount, push button actuator. Quick disconnect terminals also are available.

Further information about the switch is available from the firm.

Deflection Systems and Components Brochure

A full line of precision deflection systems, and components designed for ITV and broadcast cameras and other cathode ray tube applications are described and illustrated in a 6-page brochure just issued by **Industrial and Audio Products Dept., Radio Corporation of America,** Camden, N. J.

Included are commercial and ruggedized components for image orthicons, vidicons, TV monitors, radar, flying spot scanners and compositrons. For copies of the brochure, request Form 3R 3295.

(Continued on page 152A)

P
H
O
PHOENIX
N
I
X

At the crossroads of opportunity for men in Electronics

GOODYEAR AIRCRAFT CORPORATION
ELECTRONIC LABORATORY

ENGINEERS
IMMEDIATE OPENINGS
ELECTRONIC PACKAGING
RELIABILITY
CIRCUITRY
TEST EQUIPMENT
ELECTRO-MECHANICAL
COOLING SPECIALIST

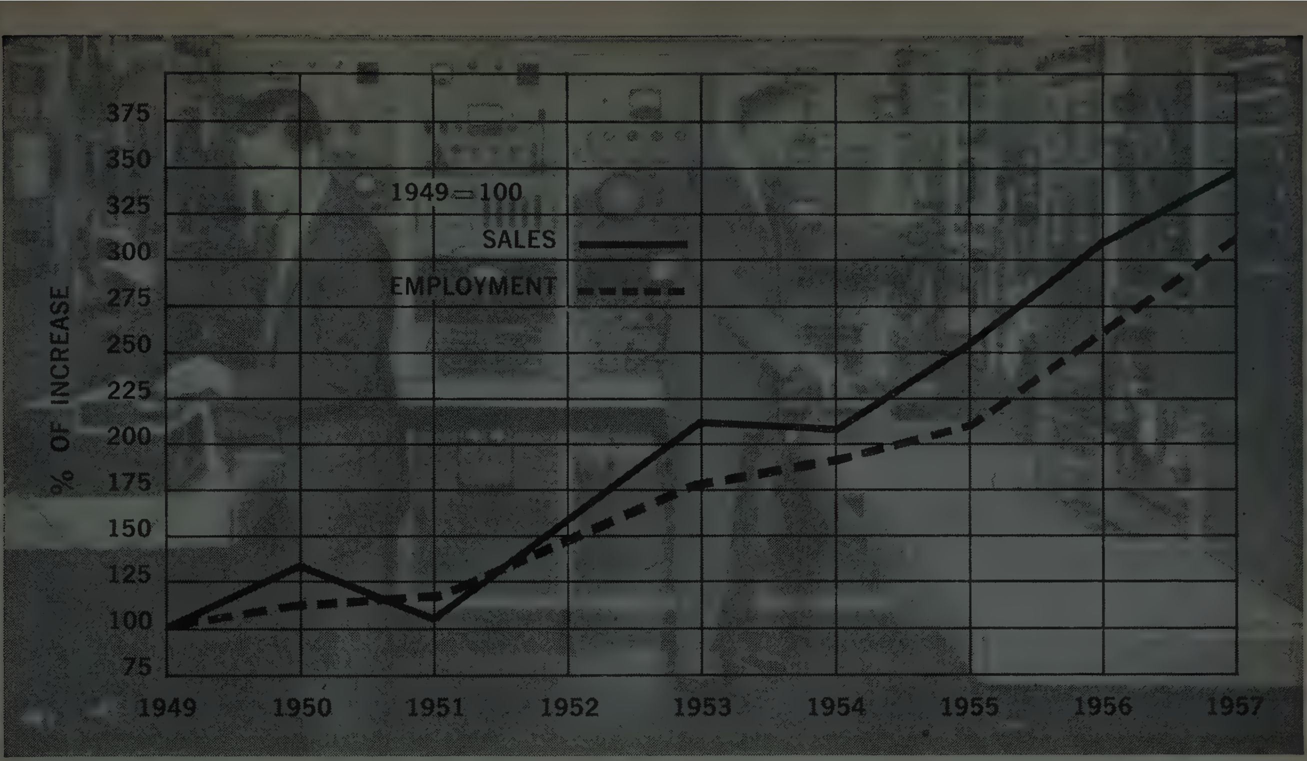
LEISURE LIVING AT ITS BEST
"IN THE VALLEY OF THE SUN"

Modern Inexpensive Housing

Send resume to A. E. Manning
Engineering and Scientific Personnel

GOODYEAR AIRCRAFT
LITCHFIELD PARK, PHOENIX, ARIZONA

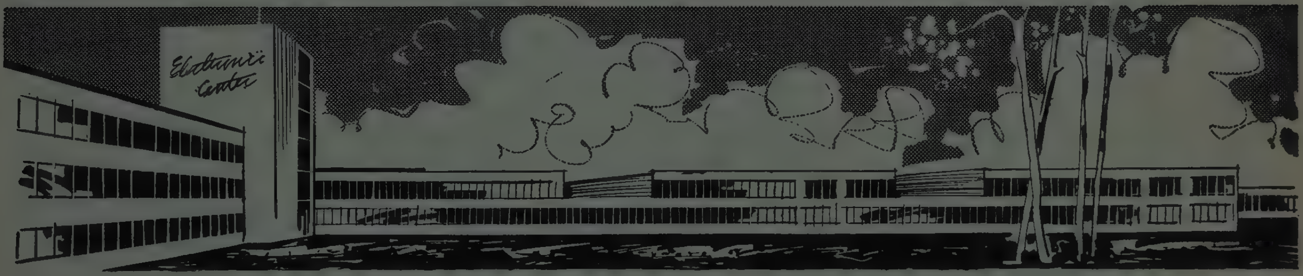
Similar opportunities available in our Akron, Ohio Laboratory.



ENGINEERS AND SCIENTISTS

CHART YOUR GROWTH WITH STROMBERG-CARLSON

Fast-growing division of General Dynamics



Your opportunities for personal and professional growth are closely related to the progress of the company you work for.

Above is a dramatic illustration of the growth of Stromberg-Carlson since 1949. Our sales have increased by 249%, personnel by 221%. *And our growth is continuing*—stable, orderly growth because our business is well-balanced between consumer and military products.

If you want to grow with us, we'd like to hear from you. We're particularly interested in men with substantial experience in solid state circuitry. You may qualify for current openings in some of today's most fascinating scientific and technical fields. For example:

- Missile Electronics
- Commercial Electronics
- Air Traffic Control
- Telecommunications
- Countermeasures
- Nucleonics
- Electroacoustics
- Automation

You would be located in Rochester, N. Y., a beautiful, progressive city in the heart of the Upstate vacation area. You'd enjoy an invigorating four-season climate; unsurpassed facilities for education and such leisure-time activities as outdoor sports, music and drama.

To arrange for a personal interview at your own convenience, send a complete résumé now to:

FRED E. LEE, *Manager*
of Technical Personnel.

S·C STROMBERG-CARLSON

STROMBERG-CARLSON
A DIVISION OF GENERAL DYNAMICS CORPORATION
1404 N. GOODMAN STREET • ROCHESTER 3, N. Y.
Electronic and communication products for home, industry and defense

GD GENERAL DYNAMICS

CHEMICAL AND PETROLEUM ENGINEERS
ELECTRONIC ENGINEERS
PHYSICISTS
COMPUTER ENGINEERS

DIGITAL COMPUTERS FOR PROCESS CONTROL

The Thompson-Ramo-Wooldridge Products Company is seeking engineers and scientists to participate in the design and application of digital computer systems for the control of manufacturing processes, especially in the petroleum and chemical industries. Staff members work on a variety of processes, studying various control problems and synthesizing control systems which take into consideration the complex factors governing optimum process operation. Applicants holding advanced degrees in engineering, physics, or chemistry are preferred.

Those interested are invited to write to the
Director of Engineering,
THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS COMPANY
POST OFFICE BOX 45067, AIRPORT STATION, LOS ANGELES 45, CALIFORNIA

STANFORD RESEARCH INSTITUTE

Has Responsible Professional Opportunities in Applied Electronic Engineering Fields for

ELECTRONIC ENGINEERS
PHYSICISTS
MATHEMATICIANS

Opportunities in the Following Research Activities:

PROPAGATION
CONTROL SYSTEMS
COMPUTER DEVELOPMENT
MICROWAVE COMPONENTS
SYSTEMS ANALYSIS
ANTENNAS
COMMUNICATION TECHNIQUES
MATHEMATICAL RESEARCH
DISPLAY DEVICES

SRI

The continuing growth of activities at SRI offers excellent opportunities for qualified personnel on the MS and PhD levels with at least 5 years of experience in Electronic Engineering or Applied Physics.

Projects are varied and professionally challenging, offering unique opportunities to develop personal competence and broad experience.

Stimulating association, good research facilities and responsible assignments, coupled with living and working in one of the most desirable areas of the San Francisco Bay Area, compliment an atmosphere conducive to professional growth and development.

Write to...
PROFESSIONAL EMPLOYMENT MANAGER
STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA

Advance study opportunities available in the area.

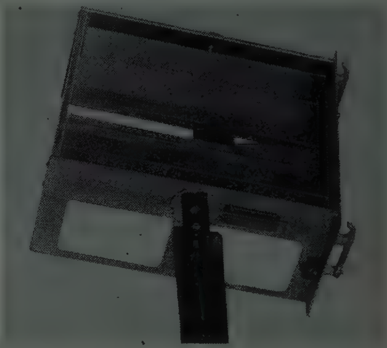
NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 150A)

Chassis Panel and Slide Package

A package assembly with exceptionally rigid full or modular chassis includes panel, handles and 'Chassis-Trak' completely assembled ready for rack mounting. The user need add only component holes to this new hardware unit sold by **Sales Engineering, Western Devices, Inc.,** 600 W. Florence Ave., Inglewood, Cal.

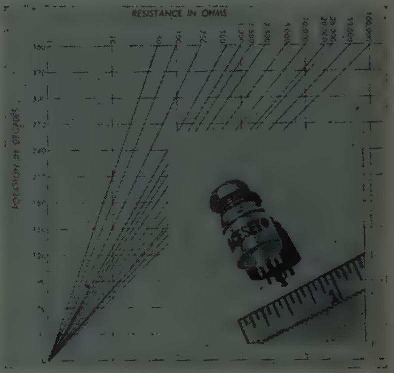


This item expedites final design and permits, after initial simple installation, instant and complete access to entire tube and wiring sections. Chassis glides on permanent lubrication or rollers, and may be released for removal if necessary by a touch of a finger. Available in a wide range of sizes, materials and finishes. Top quality heavy duty construction.

For complete data write to the firm.

Micro-Miniature Potentiometer

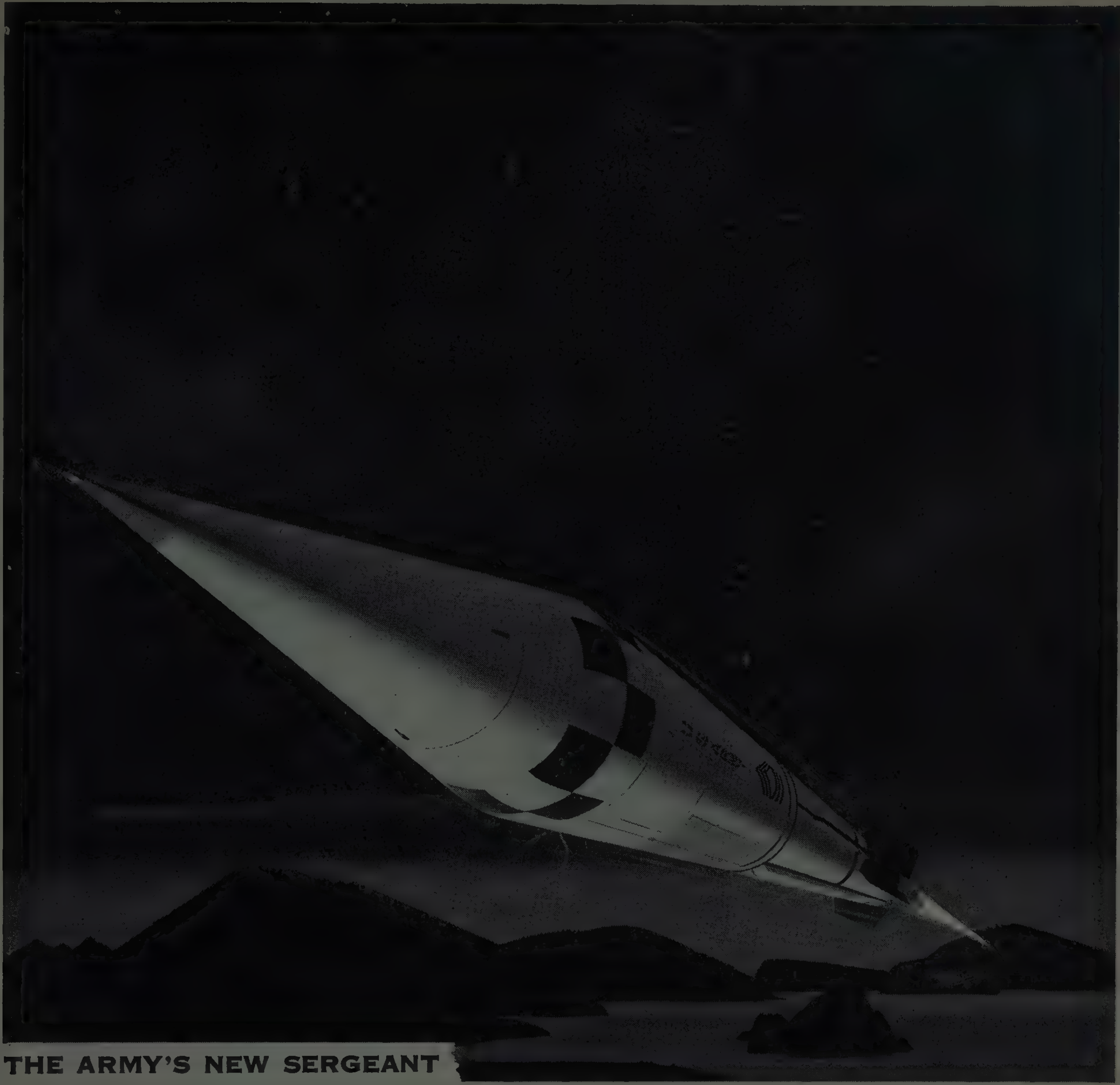
Ace Electronics Associates, Inc., 99 Dover St., Somerville, Mass., have announced the addition of 50 ohm, 15K, 50K and 100K resistance values for Aceset micro-miniature, precision, wirewound potentiometers. These units are now immediately available in thirteen different resistance values between 50 and 100,000 ohms where formerly they were available in only nine different values.



Acesets are said to offer greater tem-

(Continued on page 154A)

NOTABLE ACHIEVEMENTS AT JPL . . .



THE ARMY'S NEW SERGEANT

JPL is proud to have the responsibility of designing and developing the U.S. Army's newest operational missile system—the Sergeant. This weapon is America's first truly "second generation" surface-to-surface tactical missile and, when placed in production will eventually succeed the Corporal which was also a JPL development.

The Sergeant, especially designed as an extremely mobile tactical weapon, utilizes a solid propellant rocket motor which provides better field handling and storage capabilities than those of many other weapon systems. It can deliver a nuclear blow deep into enemy territory and its highly accurate guidance system is invulnerable to any known means of enemy countermeasure.

All elements of the Sergeant are particularly designed for active field use with emphasis on reliability, mobility and the use of standard U.S. Army vehicles wherever possible. The erector-launcher, for example, is capable of rapid movement over rough terrain. These characteristics place in the hands of the U.S. Army an important new tactical element of extended range.

The basic activity at JPL continues to be—research into all scientific fields related to the development of weapons systems and space research vehicles.

CAREER OPPORTUNITIES NOW OPEN IN THESE FIELDS

ELECTRONIC, MECHANICAL, CHEMICAL AND AERONAUTICAL

ENGINEERING • PHYSICS AND MATHEMATICS

jpl

JET PROPULSION LABORATORY
A DIVISION OF
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA • CALIFORNIA

ELECTRICAL

ENGINEERS

are invited to join the Lincoln Laboratory scientists and engineers whose ideas have contributed to new concepts in the field of electronic air defense.

A brochure describing the following Laboratory programs will be forwarded upon request.

HEAVY RADARS
MEMORY DEVICES
TRANSISTORIZED DIGITAL COMPUTERS
SCATTER COMMUNICATIONS
SOLID STATE
AEW (air-borne early warning)
SAGE (semi-automatic ground environment)
SYSTEMS ANALYSIS

In certain of these programs, positions of significant professional scope and responsibility are open to men and women with superior qualifications.

Research and Development

MIT

LINCOLN LABORATORY
BOX 16
LEXINGTON 73, MASSACHUSETTS

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 152A)

perature cycling stability than other types of comparable size. This is made possible through the use of 20 ppm temperature coefficient wire. Electrical specifications feature: heat dissipation: 2 watts at 60°C; voltage breakdown: 1,000 vdc; electrical angle: 325° nominal; resistance tolerance: ±10 per cent; linearity ±5 per cent.

Mechanical specifications feature: One piece precision-machine metal case, Passivated stainless steel shaft, Self-contained locking device, Panel antirotation pin, Mechanical rotation: 330° nominal, Size: $\frac{1}{2}$ inch diameter × $\frac{5}{16}$ inch body length. Write for Aceset Technical Bulletin.

High Temperature Converter

Jordan Electronics, Div. of Victoreen Instrument Co., 3025 W. Mission Rd., Alhambra, Calif., is now in production with a new high temperature dc to dc converter. Advanced circuitry using latest silicon power transistor makes possible operation above 100°C with excellent regulation and low ripple. As small as 1.3 pounds and 26 cubic inches, this new converter has an output from 20 to 40 watts.

In addition to the small size and light weight, this new transistorized converter has the following features: temperature

(Continued on page 156A)

ENGINEERS
FAIRCHILD SEMICONDUCTOR CORP.

Your chance to move to the beautiful San Francisco Bay Area. A rapidly growing new company with advanced semiconductor products and a high-calibre staff. Unusual opportunities for professional growth and personal advancement for:

APPLICATION ENGINEERS
Degree in E.E. and several years of experience in transistor circuitry and semiconductor application engineering.

PROCESS ENGINEERS
Degree in Engineering or Science and several years of experience in developing processes for semiconductor manufacture.

PRODUCTION ENGINEER
Engineering degree with semiconductor or similar experience. Will be responsible for the output and quality of pilot production.

QUALITY CONTROL ENGINEER
Experience in inspection and quality control for semiconductors or similar products.

Please submit resume to
Professional Personnel Director

FAIRCHILD SEMICONDUCTOR CORP.
844 Charleston Road
PALO ALTO, CALIF.

Confidential interviews will be arranged. Generous moving allowance to engineers who are accepted.

ELECTRONIC ENGINEERS

You are invited to investigate the many opportunities now available to qualified engineers in research and development at Collins Radio Company, a leader with great diversity in advancement of radio electronics including the specific fields of single sideband, scatter, microwave, Doppler, space vehicle tracking and communication, high speed data communication, and general programs of improvement of airborne and ground communication and navigation systems.

AMONG POSITIONS IMMEDIATELY AVAILABLE ARE THOSE FOR:

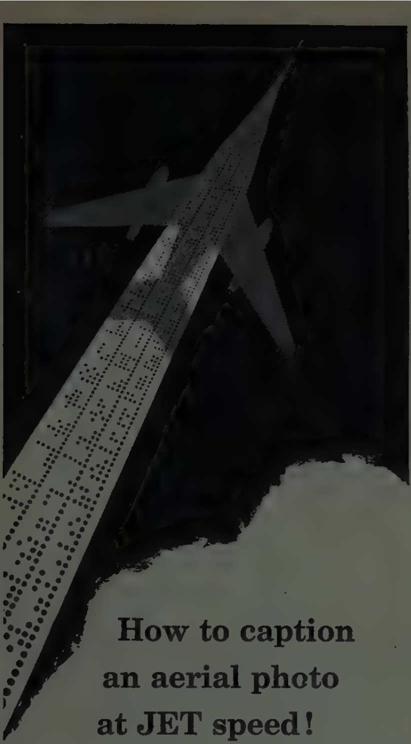
Reliability Engineers
Challenging work relative to reliability analysis, product improvement for complex systems, and reliability predictions.

Systems Engineers
Systems analysis and design in air and ground communication and navigation including fields of SSB, UHF-VHF scatter, and airborne systems.

Aircraft Instrument, Control and Flight Analysis Engineers
Design, development and analytical investigations of flight controls, computers, directors, and instruments.

Write for the brochure describing the Collins Laboratories or send a resume of your technical interests and experience to Mr. Larry Nuss, Director of Technical Recruiting, Collins Radio Company, Cedar Rapids, Iowa.

COLLINS



How to caption an aerial photo at JET speed!

NOW United States Air Force pilots can record pertinent data in code and photograph the target on the same film—simultaneously—while flying at *jet* speed!

Digital Data Recording Device, a new development of ITT Laboratories, makes this feat possible for the first time.

This is a typical example of the major projects continually being developed by this important domestic division of the ITT system. Right now our scientists and engineers are busy in air navigation systems, missile guidance, countermeasures, computers, data processing, over-the-horizon microwave, electron tubes, antennas, semi-conductor devices, and many other challenging fields... with broad opportunities for achievement, recognition, and steady growth.

Located on both coasts and in the midwest, ITT Laboratories are outstanding for their modern facilities ... the high quality of their leadership ... the excellence of working conditions and benefits.

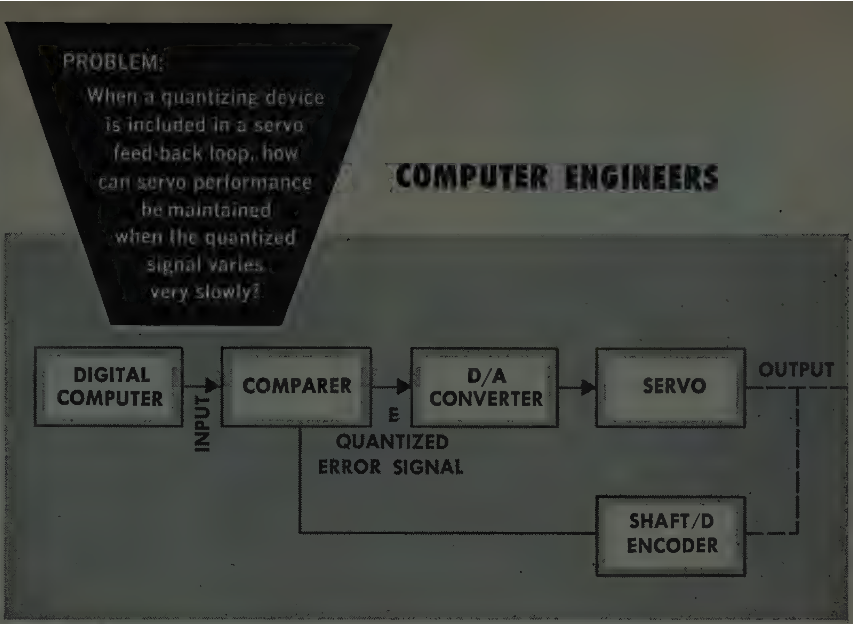
Qualified men who would like to know more about ITT Laboratories are invited to write to ITT Technical Placement Office, 67 Broad Street, New York 4, N. Y.

ITT LABORATORIES

A Division of

ITT

INTERNATIONAL TELEPHONE
AND TELEGRAPH CORPORATION
67 Broad Street • New York



PROBLEM:

When a quantizing device is included in a servo feed-back loop, how can servo performance be maintained when the quantized signal varies very slowly?

COMPUTER ENGINEERS

GENERAL ELECTRIC OFFERS EXCEPTIONAL OPPORTUNITY TO THE COMPUTER ENGINEER WHO CAN MEET THESE REQUIREMENTS:

...an engineer qualified by his versatility and experience to act as multi-project advisor in the Ordnance Section of General Electric's Missile & Ordnance Systems Department. A specialist able to determine digital control requirements and specify basic digital systems design for digital computers.

This man will play a key role working with development groups to design computer subsystems for inertial guidance and control elements of TOP PRIORITY WEAPON SYSTEMS. To carry these responsibilities he must have at least 10 years' experience in electronics, plus demonstrated knowledge of military computer applications. Ability to ride herd on development until schematics are translated into functioning hardware is essential to this position.

Specific requirements: BS (EE or Physics) plus design & development experience in pulse and digital circuits, computer logic and memory, transistor circuits, military computer applications, systems philosophy.

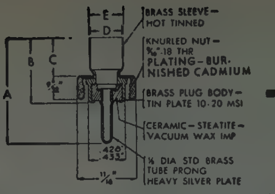
Ordnance Section is based in Pittsfield, Mass., heart of the Berkshire summer and winter recreation country.

Send resume in confidence to:
Mr. W. S. Fielding, Ordnance Section, Div. 48-MT
Missile & Ordnance Systems Dept.

GENERAL ELECTRIC

Pittsfield, Mass.

Ideal for
ANTENNA
CONNECTIONS
PHOTO-CELL WORK
MICROPHONE
CONNECTIONS


E
D
A
B
C
BRASS SLEEVE—HOT TINNED
KNURLED NUT—⁵⁄₁₆"-18 THR PLATING—BURNISHED CADMIUM
BRASS PLUG BODY—TIN PLATE 10-20 MSI
CERAMIC—STEATITE—VACUUM WAX IMP
⅛ DIA STD BRASS TUBE PRONG HEAVY SILVER PLATE
.420"
.433"
11/16"

SUPPLIED IN 1 & 2 CONTACT TYPES

JONES
SHIELDED TYPE
PLUGS & SOCKETS

P-202-CCT

P-101-¼

LOW LOSS PLUGS AND SOCKETS FOR
HIGH FREQUENCY CONNECTIONS

For quality construction thruout, and fine finish, see diagram above.
101 Series furnished with ¼", .290", 5/16", ⅜", or ½" ferrule for cable entrance. Knurled nut securely fastens unit together. Plugs have ceramic insulation; sockets bakelite. Assembly meets Navy specifications.

202 Series Phosphor bronze knife-switch type socket contacts engage both sides of flat plug contacts—double contact area. Plugs and sockets have molded bakelite insulation.

For full details and engineering data ask for Jones Catalog No. 21.

S-202-B

S-101

JONES MEANS *PROVEN* QUALITY

See New Developments at the WESCON Show—Booths 401-402.

Jones
HOWARD B. JONES DIVISION
CINCH MANUFACTURING CORPORATION
CHICAGO 24, ILLINOIS
SUBSIDIARY OF UNITED-CARR FASTENER CORP.

RADIO RESEARCH INSTRUMENT CO.

550
FIFTH AVE.
NEW YORK
JUDSON
6-4691

F-28/APN-19 FILTER CAVITY

Jan. spec: Tuneable 2700-2900mc, 1.5db max. loss at ctr freq over band. Details: Insertion loss variable. Single tuned filter for freq channelling in radar beacon. Invar center tuning conductor ¾ wavelength. New $37.50 each.

AN/MPN-1A GCA SET

Ground control approach equipped trailer with 3 cm precision and 10 cm search radars plus full complement precision and search indicators. All in original trailer. Call—write for info. and price.

3CM. Precision Tube Mount. Waveline model 688. X band shielded klystron mount PRD signal generator type. Complete with variable glass vane attenuator. Brand new. $205. list. Price $64.50.

ANTENNA PEDESTAL
SCR 584—MP 61B

Full azimuth and elevation sweeps. 360 degree azimuth. 210 degree elevation. For full tracking response. Includes pedestal drives, selsyns, etc. Excellent used condition. (Illus.) This is the first time these pedestals have been available for purchase. Limited quantity in stock for immediate shipment.

Complete description in McGraw-Hill Radiation Laboratory Series, Volume I, page 284 and page 209, and Volume 26, page 233.

3CM. KLYSTRON
MOUNT

2K25 723A/B mount with cplg. to waveguide run and afc. Shielded incl. tuning rod. Matching tuneable output slugs. Dual crystal mount. Pwr cable w/min. plug. Brand new. $28.50.

2 Watt X Band Power Source: mfg. Sperry. Delivers 2 full watts RF at X band. 6 ft. rack 115v ac input. Brand new. Also delivers 1 watt at C band (4000mc) and 750mc rf. Price complete with all tubes, gtd. $2500.

⅞" RIGID COAX. 50 ohm, standard fittings, 10cm stub supported. 12 ft. lengths. Silver plated. New $34.50 each. 12 ft. length. Right angle bends $6 ea.

CRYSTAL MOUNT X band. Broad banded. BNC (teflon) output. UG39 Flange Input. Mfg. Airtron. New, $24.50.

TOPWALL HYBRID JUNCTION. 8500-9600mc 1x.5 wg size. Broad banded better than 16%. Aluminum casting. $15.00 new. Crossover output, 1x.5 wg size. $5.00 new.
BROAD BAND BAL MIXER using short slot hybrid. Pound type broad band dual balanced crystal holder. 1x.5 wg size. $25.00 new.

FLEXIBLE WAVEGUIDE. 1x.5 X band 9" Technicraft. New $10.00. 1x.5 X band 24" Airtron. New $21.50. 1¼ x ⅝" X band 12" Western Elec. New $19.50.

RADIOSONDE TRACKING RADAR. AN/SMD-1 (ANGMD-1) Mfg. General Electric 1700 MC System consists of console, dyanamo amplifiers, synchro amplifiers, antenna system, transmitter, receiver. Price $6500.

3KW 400 CYCLE SOURCE

Complete generator set 115vdc 4HP motor (easily swapped for standard GE or other 115v 60 cycle AC motor) speed regulated. Generator output 115 volts 400 cycle single phase 17.4 amps continuous duty. Output electronically regulated. Built to rigid US Navy spec. In excellent used condition. A new special price $285.00. With 115VAC 60 cycle single phase motor $385 incl. compl. regulator.

FOR SALE COMPLETE SCR 584 RADAR

An unusual opportunity to own a much desired radar system. SCR 584 known the world over has an ideal antenna system (search, track, full azimuth, full elevation), PPI indicating system, high power pulsed transmitter (S band), klystron sensitive receiver, data transmission net. Fully housed in large, heated mobile trailer van. Our 584 is in like new condition, ready to go, and in stock for immediate delivery. Ideal for research and development, airway control, limited GCA, missle tracking balloon tracking, weather forecasting, anti-aircraft defense, tactical air support. Write us.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 154A)

range from 40°C to 120°C. Input available from 12 to 30 volts. Output available from 6 to 300 volts. Regulation line and load ±1 per cent, temperature line and load ±5 per cent. Ripple on output—1 volt peak to peak at 2 kc or less. Shock, vibration and other environmental requirements per MIL specifications for missile application.

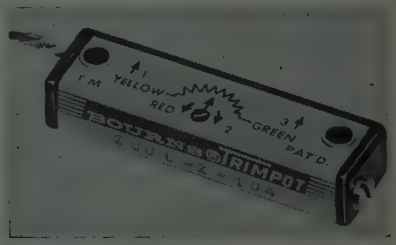
For additional specifications, write to the firm.

Military Variable Resistor Bulletin

Chicago Telephone Supply Corp., Elkhart, Ind., has just issued two stock sheets listing and offering immediate delivery from stock on 158 types of military composition variable resistors certified to latest MIL-R-94B spec (Stock Sheet No. 163) and on 108 types of military wirewound variable resistors certified to latest MIL-R-19A specs (Stock Sheet No. 164).

Wire-Wound Potentiometer

A new Trimpot* screw-actuated potentiometer with a resistance range to 100,000 ohms is now available from **Bourns Laboratories, Inc.,** P.O. Box 2112, Riverside, Calif. Designated No. 200L-2-104, this new Trimpot is based on an improved design which provides a large winding volume in a miniature unit measuring only $\frac{1}{4} \times \frac{5}{16} \times 1\frac{1}{4}$ inches.



Precision windings are made on a ceramic card and terminated by the Silverweld technique, an exclusive Bourns development. Silverweld offers unusual stability as well as zero end settings.

The new 100K Model 200 has high stability, and excellent shock and vibration characteristics. Resolution is 0.14 per cent. Power rating is 0.25 at 70°C. Maximum operating temperature is 105°C. Like all Trimpot potentiometers, this unit meets or exceeds most military specifications.

The unit has insulated, stranded wire terminals. It is similar in general design to other Trimpot potentiometers, and features space-saving size and shape, screwdriver actuation through 25 turns of rotation for adjustment accuracy.

* Reg. T.M.

(Continued on page 158A)

his unconversance with certain microwave measurements is curable—with a D-B CATALOG

Friends, this microwave engineer lacks facts on low Qs in cavities. Not knowing where to find the facts, he's stymied. Actually, all he has to do is consult his D-B catalog. Compacted into its 180 pages are complete data on making microwave measurements. He gets clear, comprehensive theory wedded to practical help on procedure. He'll find actual drawings of test setups, plus instructions on how to operate them, using units in the peerless D-B line of precision test equipment—largest line extant today.

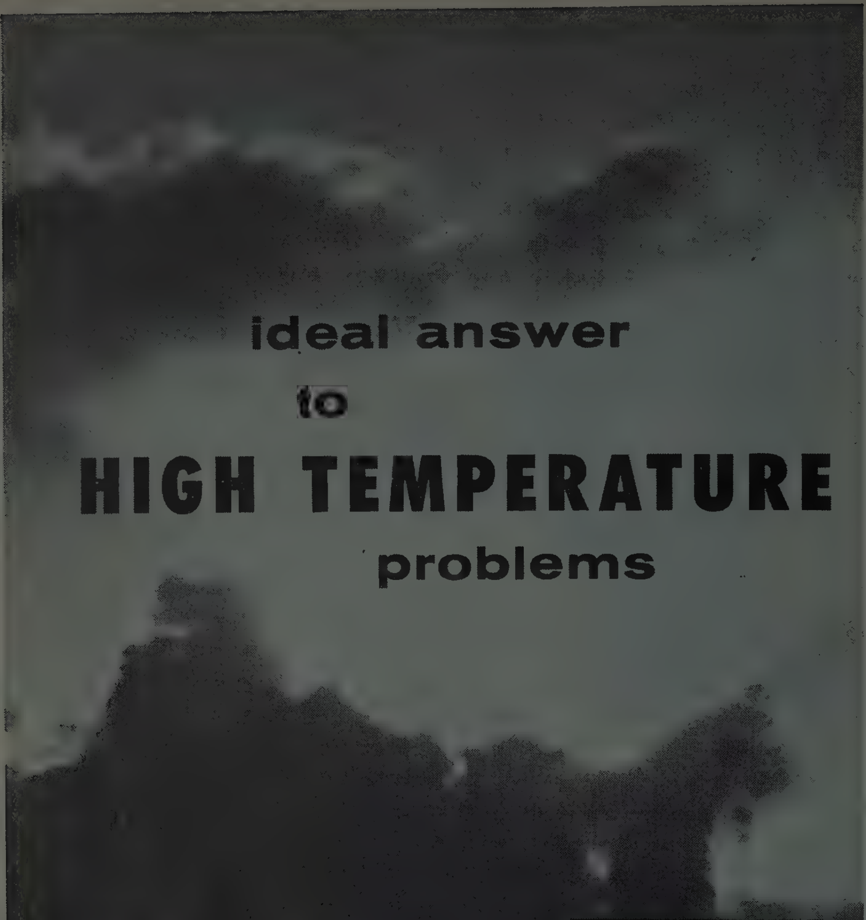
FURTHER INSPECTION WILL REVEAL a solid section on introductory concepts to microwaves—for use by purchasing personnel, inspecting individuals, and other initiates to this superlative subject.

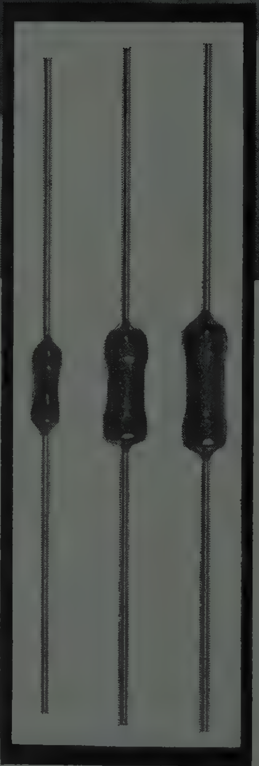
THERE'S A HABIT-FORMING HANDBOOK complete with graphs and tables on microwave tube characteristics... on conversion factors, and other daily-used data. There are dimension drawings on every AN flange in use. There's all the information needed to hook up D-B equipment to D-B equipment, or to any other equipment.

ALL THIS DATA is right in the lil' old D-B catalog No. C3, ready to assist in making more meritorious measurements. Please tell our engineer friend to use his D-B catalog. And if yours is on permament "loan," let us know. We will replace it.

DE MORNAY BONARDI

DE MORNAY-BONARDI
780 S. Arroyo Parkway, Pasadena, California





NEW ELECTRA SERIES 125 precision film RESISTORS

Now, when high temperature is the problem, you've got the answer . . . exclusive, new **Electra Series 125**, precision film resistors. Subjected to 125° C under full load for 1,000 hours, the change is less than 1%. Likewise, subjected to 95% humidity with full wattage using standard mil cycle for 250 hours, the change is less than 1%. Available in ⅛, ¼ and ½ watt sizes, values 10 ohms through 5 meg ohms . . . meet or exceed all Mil-R-10509B test requirements.

Write today for full details.

See Electra Display
Wescon Show
Booths 408-409

ELECTRA Manufacturing Co.
4051 Broadway WEstport 1-6864 Kansas City, Missouri

(Continued from page 156A)

Tubeless DC Supply Data Sheet

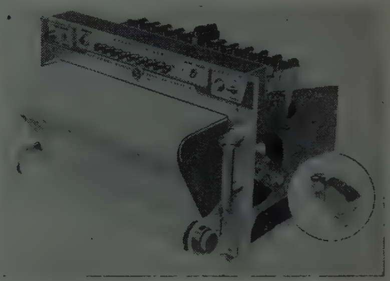
Now available from **Sorensen & Company, Inc.,** Richards Ave., South Norwalk, Conn., is a technical data sheet describing their Model MA28-125 tubeless dc power supply. This is a high-powered unit with an output of 0–125 amperes over a regulated voltage range continuously variable from 18 to 36 vdc.

Features highlighted in the data sheet include ±0.1 per cent typical regulation accuracy, 1 per cent maximum ripple, less than 0.1 second response time, and external sensing terminals.

Copies of the MA28-125 technical data sheet are available from the firm.

12 Channel Recorder

Massa Laboratories, Inc., 5 Fottler Rd., Hingham, Mass., announces the introduction of a new 12 channel rectilinear recorder, Model RE-12, a compact, high speed, multichannel, quality instrument.



Model RE-12 features true rectilinear motion with excellent transient response, and is free of resonant peaks, overshoot, and ringing. It has a wide frequency range, dc to 200 cps, and records with ink or electric writing. Push button selection permits 18 chart speeds from ½ cm/hr to 200 mm/sec. An event marker provides one second markings and a footage indicator shows the remaining amount of chart in the recorder. Remote operation is possible with a plug-in control unit. Designed for 19 inch rack mounting, the recorder is 19 inches wide by 12¼ inches high and 16 inches deep and weighs 56 pounds. The recorder element is the Model M-133A with the following specifications: Sensitivity: 20 ma rms full scale; Impedance: 1000 ohms nominal; Dimensions: 4⅛ L×3 H×1¼ inches W; Weight: 1¼ pounds.

Available equipment and accessories include a dual channel dc amplifier, Model M-220, which is a high gain stabilized amplifier for operating all Massa recorders over range dc to 200 cps. The Model M-220 has sensitivity ranges of 12 steps from 5 mv/mm to 20 v/mm. Recorder accessories include electric power supplies for electric writing, chart rolls with true rectangular coordinates for ink and electric writing, and pens for ink or electric writing.

Write to the firm for Product Data Sheet RE-12.

(Continued on page 160A)

Movable antenna at the Mullard Radio Astronomy Observatory, Cambridge University, England.

TOP LEVEL

information on British design & development

★ ELECTRONIC & RADIO ENGINEER

the magazine for designers, engineers and research workers

Month by month, this leading authority provides comprehensive coverage of world progress in electronics, radio and television. Advanced articles on theory, design and development include many original papers by physicists and engineers of international repute. The journal has the support of an Editorial Advisory Board representing Universities, the Department of Scientific and Industrial Research, the British Broadcasting Corporation and British Post Office.

Published monthly 1 year $7.50 3 years $15.00

★ WIRELESS WORLD

covering the general field of electronics radio and television

Britain's leading technical magazine in its field, WIRELESS WORLD provides a complete, accurate survey of the latest techniques in design and manufacture the world over. Every phase of radio, television and electronics practice is covered. Articles by experts provide authoritative information on current theory. Technical news of the wider aspects of international radio and design data and circuit diagrams for every application are also included.

Published monthly 1 year $5.00 3 years $10.00

AIL THIS COUPON TODAY

se enter my/our subscription as below:

ELESS WORLD 12 months $5.00 ☐

CTRONIC & RADIO ENGINEER 12 months $7.50 ☐

ELESS WORLD 36 months $10.00 (saving $5.00) ☐

CTRONIC & RADIO ENGINEER 36 months $15.00 (saving $7.50) ☐

ck/M.O. for $..............enclosed ☐

me later ☐

To: BRITISH PUBLICATIONS INC., 30, EAST 66TH STREET, NEW YORK, 22, N.Y.

NAME ....

ADDRESS ....

....CITY..

ZONE.. STATE.......................................

PRO/IRE

SEE US AT WESCON BOOTHS 1265-1266

for waveform analysis...

there's nothing like

LF-2

FOR FLEXIBILITY
FOR HIGH RESOLUTION

The LF-2 is a heterodyne type analyzer which automatically presents a permanent paper recording of the frequency and amplitude of components between 0.5 cps and 2250 cps.

The LF-2 is used for vibration and sound analysis of large structures or devices in which members rotate or oscillate at approximately the same or multiples of the same rate.
• acoustics • noise analysis • servo analysis • geophysical investigations • medical studies • general low frequency waveform investigations.

By analyzing waveform content—obtained through converting any given parameter into electrical energy by means of a sensing device such as a microphone or other transducer—you can
detect defects,
check variations,
make adjustments,
test production,
improve design

dependable CERTIFIED SPECIFICATIONS *for accurate data*

the pioneer is the leader

PANORAMIC'S SUB-SONIC
Waveform ANALYZER LF-2

No rigid frequency segments here! The LF-2, scan range selector provides 6 different scan widths which may be centered at almost any point of the instrument's frequency range with the variable center frequency control. Check the table below.

A maximum resolution of 1/10 cps! The LF-2's range of scan intervals and sweepwidths make possible exceptional resolution. Check the table below.

Definitive amplitude! The LF-2's dual amplitude scales—20 db linear and 40 db log—permit a broad range of comparative analyses.

Scan Range	Linear Scan Widths (cps)	Cps Resolution at Scan Intervals of		
		10 sec.*	2 min.	16 min.
X 1.0 (0—2250 cps frequency)	500 100 20	12 6 3	3.5 1.7 0.7	1.5 0.75 0.5
X 0.1 (0—225 cps frequency)	50 10 2	— — 0.7	1.0 0.5 0.18	0.5 0.25 0.1

*Useable only with external oscilloscope.

Yes, there's nothing like the LF-2. Complex? Not at all! It's as simple as this:

- For a quick overall look set dials for maximum scan width and short scan interval.
- Select area of interest.
- Select scan width and scan interval for detail and degree of resolution desired. (The narrower the scan width, the longer the scan interval, the higher the resolution.)
- Result—a quickly obtained, accurate, detailed, recording of waveform content.

Panoramic instruments are PROVED PERFORMERS in plants, laboratories and military installations all over the world. Write, wire, phone for detailed specification bulletin on this versatile tool today. There's a Panoramic Spectrum Analyzer for frequencies from 0.5 cps to 44,000 mc. Send for our new CATALOG DIGEST and ask to be put on our regular mailing list for The PANORAMIC ANALYZER, featuring application data.

PANORAMIC
RADIO PRODUCTS, INC.

522 So. Fulton Ave., Mt. Vernon, N. Y.
Phone: OWens 9-4600
Cables: Panoramic, Mount Vernon, N. Y. State

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 158A)

Marking Device

A new writing and marking device for use in laboratories and testing stations is available from **Speedry Products,** P.O. Box 97, Richmond Hill 18, N. Y. Called the Magic Marker, the implement fits into the palm of the hand and requires no dipping or filling. Just lift the cap and write or mark indelibly on almost any surface, including glass, paper, wood, cloth, metal, acetate, and even on cellophane tape. Its ink dries instantly and is waterproof and heat resistent. It writes with a felt nib that makes lines of varied widths from pen stroke to brush stroke size, depending upon which way the nib is turned. There is no danger of leaking or spilling.

The marker is suited for the quick, clear preparation of circuit drawings and wiring schematics. It may be used in the marking and identification of breadboard and test equipment components. Used in conjunction with masking tape, the brightly colored inks can be used to color code each conductor in a maze of wires. The marker is also used in making up progress charts, the preparation of proposals and manuals, the editing of reports, etc.

The marker is available in nine colors, including black and white, plus four pastel shades.

Pyramid Moves To South Carolina

Pyramid Electric Co., North Bergen, N. J., manufacturers of capacitors and selenium rectifiers are moving from their plant to Darlington, S. C. However, the firm's sales and accounting departments together with their jobber warehouse will remain in North Bergen and their manufacturing operation in Gastonia, N. C. will continue as heretofore.

The North Bergen facilities will be moved into the new 250,000 square foot location in Darlington—which will be completely equipped with air-conditioning in order to extend work into more of the higher reliability components. They plan to have some pilot lines operating in Darlington prior to moving the North Bergen facilities. In this manner there should be no disruption in production.

(Continued on page 163A)

Professional Group on Ultrasonics Engineering

One of the greatest assets of the IRE Professional Group plan is its flexibility in being able to serve equally well the many branches of the radio field, regardless of how new, small, or specialized they may be. This is convincingly demonstrated in the case of the Professional Group on Ultrasonics Engineering.

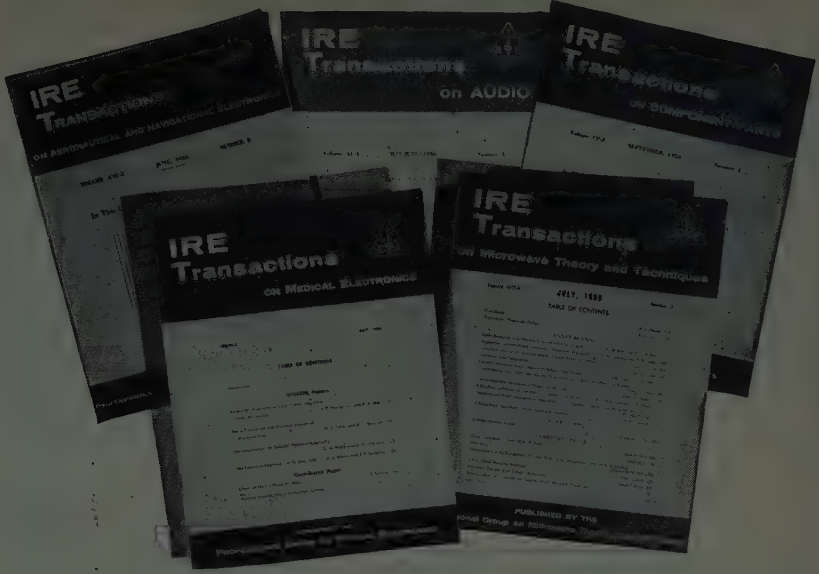
Although a relatively young field, ultrasonics already embraces many diverse fields. In the laboratory ultrasonic techniques are used for studying the properties of gases, liquids, and solids. Marine applications include ultrasonic depth indicators and underwater object locators. In the medical field ultrasonic diathermy instruments, tumor locators, dental caries locators, and even a device to replace the dentist's drill are being investigated and developed. In industry ultrasonics is finding application in nondestructive testing of materials, acceleration of chemical reactions, emulsification, coagulation, and sterilization. Ultrasonic delay lines and electromechanical filters are being used in radio, radar and digital computers. There may one day be ultrasonic washing machines.

How then is one to keep abreast of these tremendous strides? Only by receiving an authoritative technical publication devoted exclusively to this subject; only by attending meetings at which recent advances are discussed; only by exchanging ideas with other workers in the field.

It was with this purpose that the Professional Group on Ultrasonics Engineering was formed five years ago. Thanks to the *Transactions* and the Group sponsored meetings, the workers in this field are now able to keep fully informed of the diverse developments in this rapidly growing field.

W. R. G. Baker

Chairman, Professional Groups Committee


IRE Transactions on Aeronautical and Navigational Electronics
IRE Transactions on Audio
IRE Transactions on Component Parts
IRE Transactions on Medical Electronics
IRE Transactions on Microwave Theory and Techniques

At least one of your interests is now served by one of IRE's 28 Professional Groups

Each group publishes its own specialized papers in its *Transactions*, some annually, and some bi-monthly. The larger groups have organized local Chapters, and they also sponsor technical sessions at IRE Conventions.

Aeronautical and Navigational Electronics (G 11)	Fee $2
Antennas and Propagation (G 3)	Fee $4
Audio (G 1)	Fee $2
Automatic Control (G 23)	Fee $2
Broadcast & Television Receivers (G 8)	Fee $2
Broadcast Transmission Systems (G 2)	Fee $2
Circuit Theory (G 4)	Fee $3
Communication Systems (G 19)	Fee $2
Component Parts (G 21)	Fee $3
Education (G 25)	Fee $3
Electron Devices (G 15)	Fee $3
Electronic Computers (G 16)	Fee $2
Engineering Management (G 14)	Fee $3
Engineering Writing and Speech (G 26)	Fee $2
Human Factors in Electronics (G 28)	Fee $2
Industrial Electronics (G 13)	Fee $2
Information Theory (G 12)	Fee $3
Instrumentation (G 9)	Fee $1
Medical Electronics (G 18)	Fee $3
Microwave Theory and Techniques (G 17)	Fee $3
Military Electronics (G 24)	Fee $2
Nuclear Science (G 5)	Fee $3
Production Techniques (G 22)	Fee $2
Radio Frequency Interference (G 27)	Fee $2
Reliability and Quality Control (G 7)	Fee $2
Telemetry and Remote Control (G 10)	Fee $2
Ultrasonics Engineering (G 20)	Fee $2
Vehicular Communications (G 6)	Fee $2

IRE Professional Groups are only open to those who are already members of the IRE. Copies of Professional Group Transactions are available to non-members at three times the cost-price to group members.

The Institute of Radio Engineers
1 East 79th Street, New York 21, N.Y.

USE THIS COUPON

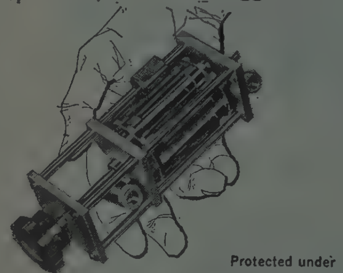
Miss Emily Sirjane PG-8-58
IRE—1 East 79th St., New York 21, N.Y.
Please enroll me for these IRE Professional Groups
....$..................
....$..................
Name ....
Address ....
Place ....
Please enclose remittance with this order.

STODDART

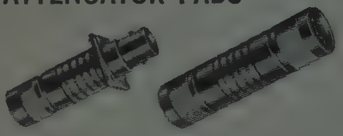
COAXIAL ATTENUATORS AND TERMINATIONS

made with exclusive Stoddart Filmistors for highly accurate and stable resistive values from dc to 3000 mc.

2, 6 and 10-position
TURRET ATTENUATORS
with simple "PULL-TURN-PUSH" operation, small and rugged.


Protected under Stoddart Patents

ATTENUATOR PADS



Available in any conceivable combination of male and female Type C and Type N connectors. Maximum length of 3" for any attenuation value.

GENERAL SPECIFICATIONS
VSWR: Less than 1.2 to 3000 mc.
Characteristic Impedance: 50 ohms.
Attenuation Value: Any value from 0 db to 60 db including fractional values.
Accuracy: ±0.5 db; values above 50 db have rated accuracy of attenuation through 1000 mc only.
Power Rating: 1.0 watt sine wave.

COAXIAL TERMINATIONS

Small-stable-50 or 70 ohms

½-Watt: 50 ohms impedance, TNC or BNC connectors, dc to 1000 mc, VSWR less than 1.2.

1-Watt: 50 ohms impedance, dc to 3000 mc or dc to 7000 mc, Type N or Type C connectors, male or female; VSWR less than 1.2, 70 ohm, Type N, male or female terminations available.

Fast delivery on all items.
Send for complete literature.

STODDART
AIRCRAFT RADIO CO., INC.
6644 Santa Monica Blvd., Hollywood 38, Calif.
HOllywood 4-9292

PROFESSIONAL CONSULTING SERVICES

Advertising rates
Professional Consulting Service Cards.

1 insertion	$ 15.00
12 insertions	$120.00

50% discount to IRE members on 3 or more consecutive insertions.
In IRE DIRECTORY $15.00 flat rate.
1 inch only, no cuts or display type.
Advertising restricted to professional engineering and consulting services by individuals only. No product may be offered for sale, and firm names may not be mentioned in cards.

RICHARD L. BICKEL
& associates
Semiconductor Automatic Testing Specialists
Production Test Equipment
System Automation and Control
Analog and Digital Circuitry
Data Handling—Transistor Applications
P.O. Box 451—Garland, Texas—BR 6-6859

J. N. CARMAN
Technical and Management Consultant
to the
SEMICONDUCTOR INDUSTRY
Product design and development
Process development
Tooling and Mechanization
Post Office Box 328, Bedford, Massachusetts
Telephone: CR 4-8232

TECHNICAL MARKETING RESEARCH
A. D. EHRENFRIED
and associates
Specialists in the planning, distribution, and promotion of electronic components, instruments, and systems.
CONCORD, Massachusetts EMerson 9-5500

NORMAN S. GOULD & Staff
Complete TECHNICAL MANUALS to Government and Commercial Specifications
writing—drafting—art illustration
photography—printing
80-46 222nd Street, Jamaica 27, New York
HOllis 8-7723

CLYDE E. HALLMARK
and associates
30 years experience specializing in Instrumentation—Automatic Control—Television—General Electronics—Semiconductor & Magnetics Application—Systems Research—Project Evaluation.
ENGINEERING SERVICE—CONTRACT R&D
New Haven Indiana

LEONARD R. KAHN
Consultant in Communications and Electronics
Single-Sideband and Frequency-Shift Systems
Diversity Reception - Modulation Theory
Television Systems
22 Pine St., Freeport, L.I., N.Y.
Freeport 9-8800

Use Your
IRE Directory!
It's valuable!

HOWARD S. KNOPOW, P. E.
& staff
Design, Research, Development, Consultation
Transformers & Reactors for
Guided-Missile, Electronic & Power Uses
7377 N. 76th Street Milwaukee 18, Wisconsin
Phone: FLagstone 3-8017

LEN MAYBERRY
ELECTRONICS CONSULTING ENGINEER
Laboratories and Staff
• Test Equipment Design • Proposal Writing
• Product Design • Engineering Assistance
111 South Oak Street ORegon 8-4847
Inglewood, California

TRANSISTOR ENGINEERING
S. Moskowitz D. D. Grieg
Product Transistorization. Complete service in consulting, research, development, and production on transistor circuitry, products and instrumentation.
67 Factory Place, Cedar Grove, N.J.
CEnter 9-3000

EVERT M. OSTLUND
Consulting Radio Engineer
Radio—Microwave—
Communication—Control—
Systems and Equipment—
Planning, Research—Development
ANDOVER, NEW JERSEY
Tel.: PArkway 9-6635

NATHAN GRIER PARKE
and Staff
Consulting Applied Mathematicians
Research • Analysis • Computation
Bedford Road • Carlisle, Massachusetts
Telephone EMerson 9-3818

PAUL ROSENBERG
& Associates
Established 1945
Consultation, Research & Development
in Applied Physics
100 Stevens Ave., Mt. Vernon, New York
MOunt vernon 7-8040 Cable: PHYSICIST

WILLIAM R. SPITTAL
& Staff
Specialize in Design and Development of
Transformers, Chokes, etc.
for the
Electronic, Industrial and Allied Fields.
90 Magnolia Street
Westbury, L.I., N.Y. EDgewood 3-2933

DON C. WALLACE
Screen Room Engineering
Line Filter Engineering
Transmitting and Traveling Wave
Tube Engineering
Nuclear Application Engineering
Bendix Building
1206 Maple Ave., Los Angeles 15, Calif.
Richmond 7-0401

HAROLD A. WHEELER
Laboratories and Engineering Staff
Consultation — Research — Development
Microwaves — UHF — VHF — VLF
Antennas and Components
HUnter 2-7876 Great Neck, N. Y.
Antenna Laboratory: Smithtown, N. Y.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 160A)

Copper-Clad Laminates Bulletin

A new bulletin titled "A Better Foundation for Printed Circuitry" is available from **National Vulcanized Fibre Co.,** 1058 Beach St., Wilmington 99, Del.

Describing a line of copper-clad Phenolite, this 6-page, 2-color folder charts performance and illustrates eleven grades of copper-clad materials for printed circuit applications. It also lists typical uses for these materials.

This new bulletin presents in tabular form typical test values for each of the grades. It also contains information on the manufacture and fabrication of copper-clad Phenolite and printed circuit assembly methods.

Copies of this new bulletin are available, without cost, from the firm.

Test Equipment Brochure

The latest **Electronics International Co.,** 145 W. Magnolia Blvd., Burbank, Calif., technical information and product brochure on Elin precision power oscillators offering an ultra-stable voltage source

(Continued on page 164A)

Kepco

VR PS*

the most complete line of...
POWER SUPPLIES

TRANSISTORIZED
MAGNETIC TUBELESS
VACUUM TUBE TYPE

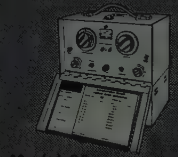
*VOLTAGE REGULATED POWER SUPPLIES

RESEARCH • MANUFACTURING

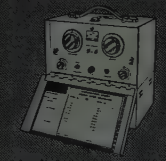
KEPCO
LABORATORIES, INC.
131-38 SANFORD AVENUE
FLUSHING 55, N. Y.
INDEPENDENCE 1-7000

JERROLD
PRECISION EQUIPMENT

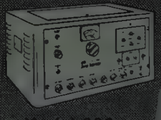
SWEEP GENERATORS



Model 95



Model 220



Model 900

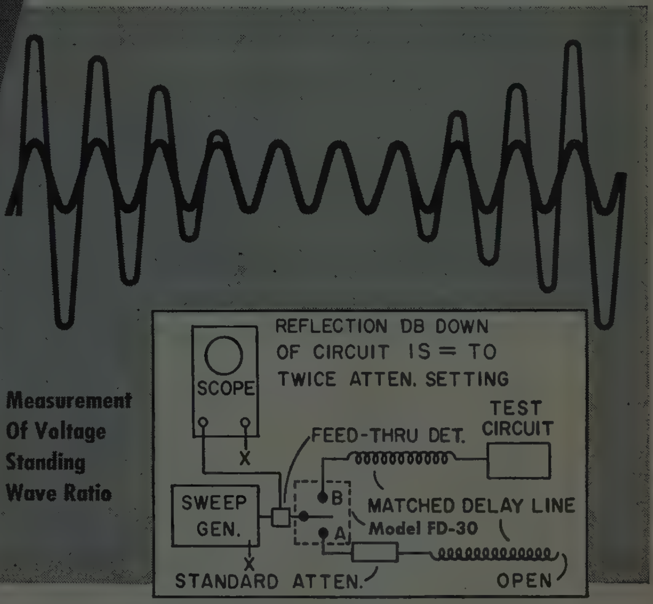
Model 601

Model 602

PERMITS ACCURATE
R.F. Measurements
By Comparison

Gain—VSWR—Loss

From 200 KC to 1000 MC



Measurement Of Voltage Standing Wave Ratio

ACCESSORIES

Switcher
Model FD-30

Osc. Preamp
Model SPR-100

Attenuator
Model AV-50

Sweep Generators and Accessories available from 15 KC to 1000 MC

Measurements Unaffected By:
- Oscilloscope Gain or Linearity Changes
- Sweep Generator Power Output Changes
- Square Law Characteristics of Detector
- Delay Line Losses

Comparison Measurement Techniques can achieve accuracies in the order of ±0.2—Without Refinement Efforts.

SEND FOR TECHNICAL NEWSLETTER

Informative, fully illustrated technical newsletter describes RF Measurements of Gain, Loss, or VSWR by the Comparison Technique.

JERROLD ELECTRONICS CORP.
15th & Lehigh • Philadelphia 32, Pa.
Export—Rocke International, N.Y., N.Y.

Dept. TED21

Visit our booth at the Wescon Show—Booth #720 and #721

▸ Metallurgists and Manufacturers . . .
Specializing in Unusually SMALL WIRE
Serving Industry—for Over 57 Years

PRECIOUS METAL WIRES
Produced in Platinum, Gold, alloys and pure metals—small diameter . . . Platinum alloy resistance wires.

BASE METAL WIRES
Very small diameter — for filaments, thermo-couples, resistance units.

COATED WIRES
Extensive range of electroplated grid wires . . . Enamel insulated wires for precision resistors and potentiometers.

ANODIZED ALUMINUM WIRE
Insulation at 800°F. Precision drawn to close resistance in smaller sizes.

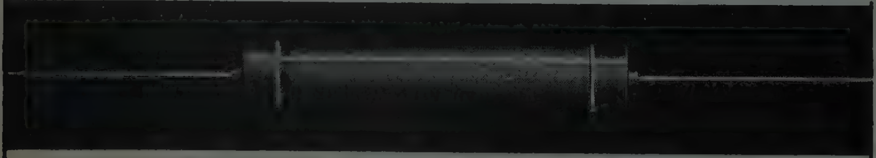
Write for List of Products

SINCE 1901

SIGMUND COHN CORP. 121 So. Columbus Avenue • Mount Vernon, N.Y.

WELWYN

High Stability Carbon Resistors



Uniformity and reliability are essential criteria in the selection of critical components. Availability is another. And these relate directly to the experience and facilities of the manufacturer.

Four full-time Welwyn Plants in Britain and in Canada are today supplying a steady flow of precision resistors to meet an ever-growing American demand. With sales engineering and service facilities operating out of Ohio, these Welwyn users in the U.S. are enjoying prompt, efficient and reliable handling of all their quality resistor requirements.

The Welwyn organization has been devoted to the study and development of carbon film techniques for nearly a quarter of a century. The value of this experience is being constantly demonstrated in the superior performance and dependability of Welwyn Carbon Resistors in critical applications.

For complete information, write to:
WELWYN INTERNATIONAL INC.
3355 Edgecliff Terrace, Cleveland 11, Ohio, or phone WInton 1-1333

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 163A)

for use in a wide variety of electronic systems will be sent free on request. The brochure is clearly illustrated.

Photographs and descriptive material on the Elin instrumentation line are presented with technical information prepared in text and graphs which explains Elin's ultra-stable power source characteristics, test results, etc.

Additional instruments described include: a time Correlation System, Bridge Channel Test and a unity gain power amplifier for airborne use.

Free copies may be obtained by writing, Sales Department, Electronics International Co.

Metallized Paper Capacitors

Type 118P Difilm metallized capacitors which utilize double insulation of both metallized paper and polyester film to give the best performance characteristics with regard to temperature and reliability are now available from the **Sprague Electric Co.**, 235 Marshall St., North Adams, Mass. Type 118P screw-neck mounting styles now have the large threaded neck mountings in case diameters 0.562 inch and above in order to improve their performance under conditions of severe vibration such as is encountered in many types of military electronic gear.

Also availabe are new Type 121P for those applications which do not require the high insulation resistance or other special performance characteristics of the Type 118P. Type 121P are an improvement over the Type 116P previously furnished for 85°C service, which had to be derated very severely when operated at higher temperatures.

Complete engineering data is given in Engineering Bulletins 2211A and 2210. Technical Paper 58-2 entitled "Some Guideposts to the Use of Metallized Capacitors" contains much interesting and useful information on the characteristics of metallized capacitors under alternating voltage conditions and will prove helpful in the proper application of metallized capacitors. The bulletins, as well as the technical paper, are available on letterhead request to the Technical Literature Section, Sprague Electric Co.

Advertising Index

E News and Radio Notes 14A
E People 26A
dustrial Engineering Notes 50A
eetings with Exhibits 8A
embership 98A
ews—New Products 20A
sitions Open 114A
sitions Wanted by Armed Forces Veterans 124A
ofessional Group Meetings 66A
ction Meetings 56A
ble of Contents 1A-2A

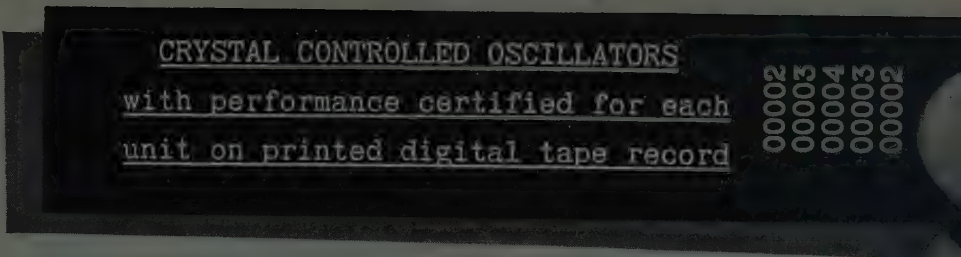
DISPLAY ADVERTISERS

bott's Employment Specialists 132A
credited Personnel Service 130A
ronutronic Systems, Inc. 138A
borne Instruments Lab. 4A
craft Radio Corp. 111A
pax Products Company 103A
en-Bradley Company ....facing 12A-13A
erican Electrical Heater Co. 102A
erican Lava Corporation 37A
erican Television & Radio Co. 64A
perex Electronic Corp. 98A
phenol Electronics Corp. 24A
drew Corporation 47A
gonne National Lab. 137A
nour Research Foundation, Illinois Institute f Technology 128A, 140A
old Engineering Co. 30A-31A
co Mfg. Corp., Crosley Div. 120A
on Div., ACF Industries, Inc. 144A

lantine Laboratories, Inc. 66A
den Mfg. Co. 33A
Aircraft Corporation 120A
Telephone Laboratories........................6A
dix Aviation Corp., Guided Missile Section 147A
dix Aviation Corp., Kansas City Div. 108A
dix Aviation Corp., Pacific Div. 132A
kel, Richard L. 162A
cher Corporation 73A
ing Airplane Company 125A
sch Mfg. Co., Inc. 62A
nac Laboratories, Inc. 29A
rns Laboratories, Inc. 27A
kbee Mears Company 50A
mann Mfg. Div., McGraw Edison Co. 82A

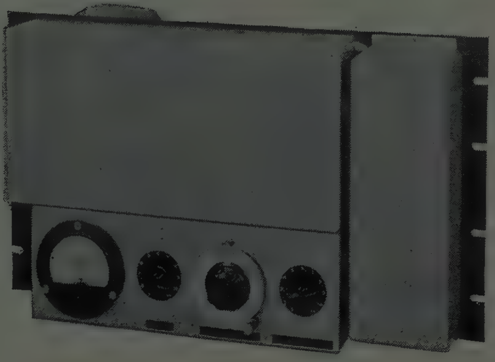
—Hytron Div. 13A, 65A
edonia Electronics & Transformer Corp. 102A
f. Inst. of Technology, Jet Propulsion Lab. 153A
itol Radio Engineering Institute 74A
ad Corporation 32A
nan, J. N. 162A
masecal, Inc. 42A
n Corporation, Sigmund 164A

JK PRODUCTS



CRYSTAL CONTROLLED OSCILLATORS
with performance certified for each
unit on printed digital tape record

Crystallography, electronic circuitry, thermal and mechanical design integrated and optimized to provide maximum stability and reliability, with minimum size and weight.



PRECISION FREQUENCY STANDARDS

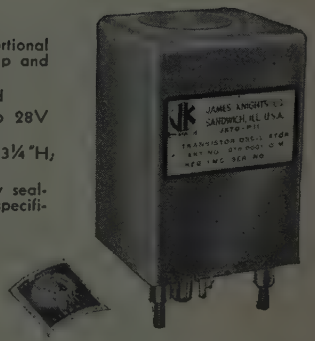
Time-Proven JKFS-1000
Stability: 1x10^{-9}/Day
Output: 5 V into 5000 ohms at 1 mc; 500 kc and 100 kc. Pulse output for measurements up to 20 mc

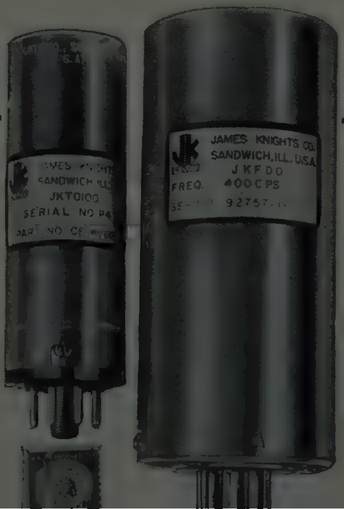
The new JKFS-1100-T
Stability: 5x10^{-10}/Day
Fully Transistorized: Built-in battery standby power source for 20 hours of operation
Output: 1 V into 50 ohm-load at frequencies of 1 mc and 100 kc.
Dimensions: 8¾" x 19" panel for rack mounting

PLUG-IN FREQUENCY STANDARDS

JKTO-P1A
Stability: 1x10^{-7}/Day
Output: 2V into 50,000 ohms at 1 mc
Power: Operates from 24 to 28V D.C.
Oven: Long life; booster and control thermostats hermetically sealed.
Dimensions: 1.8"x2"x3" H; Wt. 9 oz.
Environmental: Hermetically sealed; meets aircraft equipment specifications.

NEW JKTO-PIP
Stability: 1x10^{-8}/Day
Oven: Transistorized proportional control oven with fast warm-up and precise temperature control
Output: 2V into 50 ohm-load
Power: Operates from 24 to 28V D.C.
Dimensions: Max.1¾"x2⅜"x3¼"H; Wt. 10 oz.
Environmental: Hermetically sealed; meets aircraft equipment specifications.





A WIDE RANGE OF JKTO PLUG-IN REFERENCE OSCILLATORS

Stability: 1x10^{-6}/Day
Frequency Range: 50 cycles to 50 mc
Oven: Features long-life, new "Snap-Action" thermostat

Write for literature, giving model number, and state your specific requirements.

THE JAMES KNIGHTS COMPANY
Sandwich, Illinois

I want a "Whatcha-ma-call it?"

It's a "thinga-ma-jig that ......"

How often have you struggled to remember the name of a component or electronic item. . . . Just could not think quickly what it is called?

YOU CAN FIND IT

IN THE IRE DIRECTORY!

because

(1) The IRE Directory classifies products by purpose and use

(2) Its listings are fundamental—the way an engineer thinks

(3) "Terminology" is cross indexed in the pink pages—condensed, simple, not mixed in with firm names.

(4) Ads face listings thus helping to identify products by actual pictures.

(5) Product code numbers reduce complex and duplicate listings, saving you "searching" time and effort.

Study it . . . save it . . . work it.

THE INSTITUTE OF RADIO ENGINEERS

1 East 79th Street, New York 21, N.Y.

Collins Radio Company 154A
Computer-Measurements Corp. 44A
Consolidated Mining & Smelting Co. 74A
Continental Consultants Incorporated 74A
Cornell Aeronautical Lab., Inc. 139A
Cornell-Dubilier Electric Corp. ....Cover 3
Corning Glass Works 86A
Cubic Corporation 133A
Curtiss Wright Corporation 100A, 148A

Dale Products, Inc. 17A
DeMornay-Bonardi 157A
Dewey & Co., Inc., G. C. 140A

E S C Corporation 83A
Eastern Industries, Inc. 69A
Ehrenfried, A. D. 162A
Eitel-McCullough, Inc. 41A, 67A
Electra Mfg. Co. 158A
Electric Auto-Lite Company 57A
Electro Instruments, Inc. 109A
Electronic Research Associates, Inc. 8A
Elgin National Watch Company 40A
Emerson Electric Mfg. Co. 117A
Empire Devices Products Corp. 92A

Fairchild Semiconductor Corp. 154A
Freed Transformer Co., Inc. 56A
Fusite Corporation 51A

Gates Radio Company 146A
General Electric Company, Microwave Laboratory 138A
General Electric Company, Missile Guidance Products Section 121A
General Electric Company, Missile & Ordnance Systems Dept. 155A
General Electric Company, Receiving Tube Div. 45A
General Electric Company, Semiconductor Products Dept. 60A-61A
General Electric Company, Silicone Products Dept. 36A
General Mills, Inc., Mechanical Div. ..81A, 147A
General Precision Labs., Inc. 167A
General Radio Company ....Cover 4
General Telephone Labs. 149A
Goodyear Aircraft Corp. 150A
Gould, Norman S. 162A

Hallmark, Clyde E. 162A
Heath Company 46A
Hewlett-Packard Company 7A, 22A-23A
Huggins Laboratories 112A
Hughes Aircraft Company 25A, 122A-123A
Hycon Eastern, Inc. 54A

Iliffe & Sons, Ltd. 159A
Institute of Radio Engineers 12A, 42A, 76A, 161A
International Business Machines Corp. 143A
International Telephone & Telegraph Corp., ITT Laboratories Div. 155A

Jerrold Electronics Corp. 163A
Johns Hopkins University, Applied Physics Lab. 150A
Johns Hopkins University, Operations Research Office 124A
Jones Div., Howard B., Cinch Mfg. Corp. ..156A

Kahn, Leonard R. 162A
Kay Electric Co. 9A
Kennedy & Co., D. S. 95A
Kepco Laboratories, Inc. 163A
Knights Company, James 165A
Knopow, Howard S. 162A
Kollsman Instrument Corp. 136A
Krohn-Hite Corporation 84A

Lapp Insulator Co., Inc. 88A
Lavoie Laboratories, Inc. 55A
Librascope, Inc. 134A
Lockheed Aircraft Corp. 118A-119A

Magnetics, Inc. 77A
Marconi Instruments 104A
Martin Company 139A
Massachusetts Inst. of Technology, Instrumentation Lab. 128A
Massachusetts Inst. of Technology, Lincoln Lab. 154A
Mayberry, Len 162A
McCoy Electronics Co. 58A
Measurements, A McGraw-Edison Div. 168A
Melpar, Inc. 135A
Menlo Park Engineering 64A
Microdot, Inc. 166A
Microwave Associates, Inc. 34A
Microwave Chemicals Laboratory, Inc. 59A
Millen Mfg. Co., Inc., James 50A
Moskowitz, S., & D. D. Grieg 162A
Motorola, Inc., Semiconductor Products Div. 72A
Motorola, Inc., Western Military Electronics Centre 131A
Mucon Corporation 84A

North American Aviation, Inc. ..121A, 135A, 145A

Ohio Semiconductors, Inc. 53A
Oldsmobile Div., General Motors Corp. 99A
Ordnance Research Laboratory, Pennsylvania State University 132A
Oster Mfg. Co., John 94A
Ostlund, Evert M. 162A

Pacific Semiconductors, Inc. 97A
Panoramic Radio Products, Inc. 160A
Parke, Nathan Grier 162A
Perkin Engineering Corp. 11A
Permanent Employment Agency 127A
Philco Corporation, Lansdale Tube Div. 84A
Philips Electronics, Inc. 127A
Polarad Electronics Corp. ....facing 36A-37A
Polytechnic Research & Dev. Co., Inc. 87A

Radio Corp. of America, Electron Tube Div. 96A
Radio Corp. of America, Specialized Employment Dept. 131A
Radio Engineering Laboratories, Inc. 89A
Radio Engineering Products, Ltd. 90A
Radio Research Instrument Co. 156A
Radiometer 106A
Ramo-Wooldridge Corporation 136A

These buildings are typical of GPL's superb facilities, set in 69 acres in the heart of Westchester County.

the grass is greener at GPL Some of the most advanced engineering work being done in America today is in progress right here in this estate-like setting, less than one hour from New York City. Here, in contrast with the vast engineering "factories", outstanding men work in small groups, yet have at their disposal exceptional facilities, and enjoy every advantage of pay, recognition and advancement. Right now, GPL has openings in the areas listed below, for Electronics Engineers and Physicists of the caliber of those who have already found GPL's "greener pastures" for themselves and their families.

DIGITAL COMPUTER LOGIC DESIGN

TELEVISION ENGINEERING

RADAR RECEIVER & TRANSMITTER DESIGN

MICROWAVE ANTENNA AND WAVEGUIDE COMPONENTS

SERVO SYSTEM ANALYSIS AND DESIGN

We seek exceptional men, and are prepared to make correspondingly exceptional offers, including liberal pay, benefits and relocation allowance. At GPL you will find the combined advantages of both the vertical and horizontal engineering organization, as well as many unusual facilities (engineers' own model shop, 6 flight-test planes including a 4-engine jet, exceptionally well-equipped environmental test laboratory, etc.). And, as part of the nationwide General Precision Equipment group, GPL offers resources which assure an outstanding future for the Company and those whose careers are associated with it.

EE's and Physicists who wish to arrange for a personal discussion of their future at GPL, should call (collect) ROgers 9-5000 or send resumé to William P. Schell. Inquiries will be held in strictest confidence.

GPL | GPE GENERAL PRECISION EQUIPMENT CORPORATION

PROVIDING VISION AND DIRECTION WITH AIR NAVIGATION, AIR TRAFFIC CONTROL AND TELEVISION SYSTEMS

General Precision Laboratory Incorporated, 63 Bedford Road, Pleasantville, N.Y.
A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORPORATION

MEASUREMENTS'

NEW

VACUUM TUBE VOLTMETER

SET ZERO
OHMS ADJ. TO ∞
VACUUM TUBE VOLTMETER
MODEL 162
SERIAL 162
OFF
OHMS
AC
DC+
DC-
VOLTS
OHMS
MEASUREMENTS
A McGRAW-EDISON DIV.
BOONTON, N.J.
MADE IN U.S.A.

MODEL 162

Provides RANDOM ACCESS to all functions and ranges through the use of push-button switches.

- For voltage and current measurements in laboratories, service shops and on production lines.
- For accurate rf and ac voltage measurements from 0.1 to 300 volts on electronic equipment from the low audio range through the VHF range.
- For dc voltage measurements from 0.01 to 1000 volts without disturbing circuit performance.
- For direct current measurements as low as 0.001 microampere.

WRITE FOR BULLETIN

Laboratory Standards

MEASUREMENTS
A McGraw-Edison Division
BOONTON, NEW JERSEY

STANDARD BOLOMETER BRIDGE

The Most Accurate Means of Calibrating High Frequency Voltages

STANDARD BARRETTER BRIDGE
FOR POWER AND VOLTAGE MEASUREMENTS
MEASUREMENTS CORPORATION

MODEL 202-C

Wide frequency range—2 Mc to 1000 Mc ... True RMS response ... High accuracy, excellent stability and sensitivity ... Bolometer element in temperature-controlled oven ... 50 ohms impedance with VSWR less than 1.2.

WRITE FOR BULLETIN

Laboratory Standards

MEASUREMENTS
A McGraw-Edison Division
BOONTON, NEW JERSEY

Raytheon Mfg. Co., Commercial Equipment, Magnetic Components 80A
Raytheon Mfg. Co., Microwave & Power Tube Div. 21A
Raytheon Mfg. Co., Personnel Recruitment Div. 116A, 129A
Reeves-Hoffman Div., Dynamics Corp. of America 110A
Rheem Mfg. Co., Rheem Electronics Div. 107A
Rider, Publisher, Inc., John F. 26A
Rixon Electronics, Inc. 48A
Rosenberg, Paul 162A

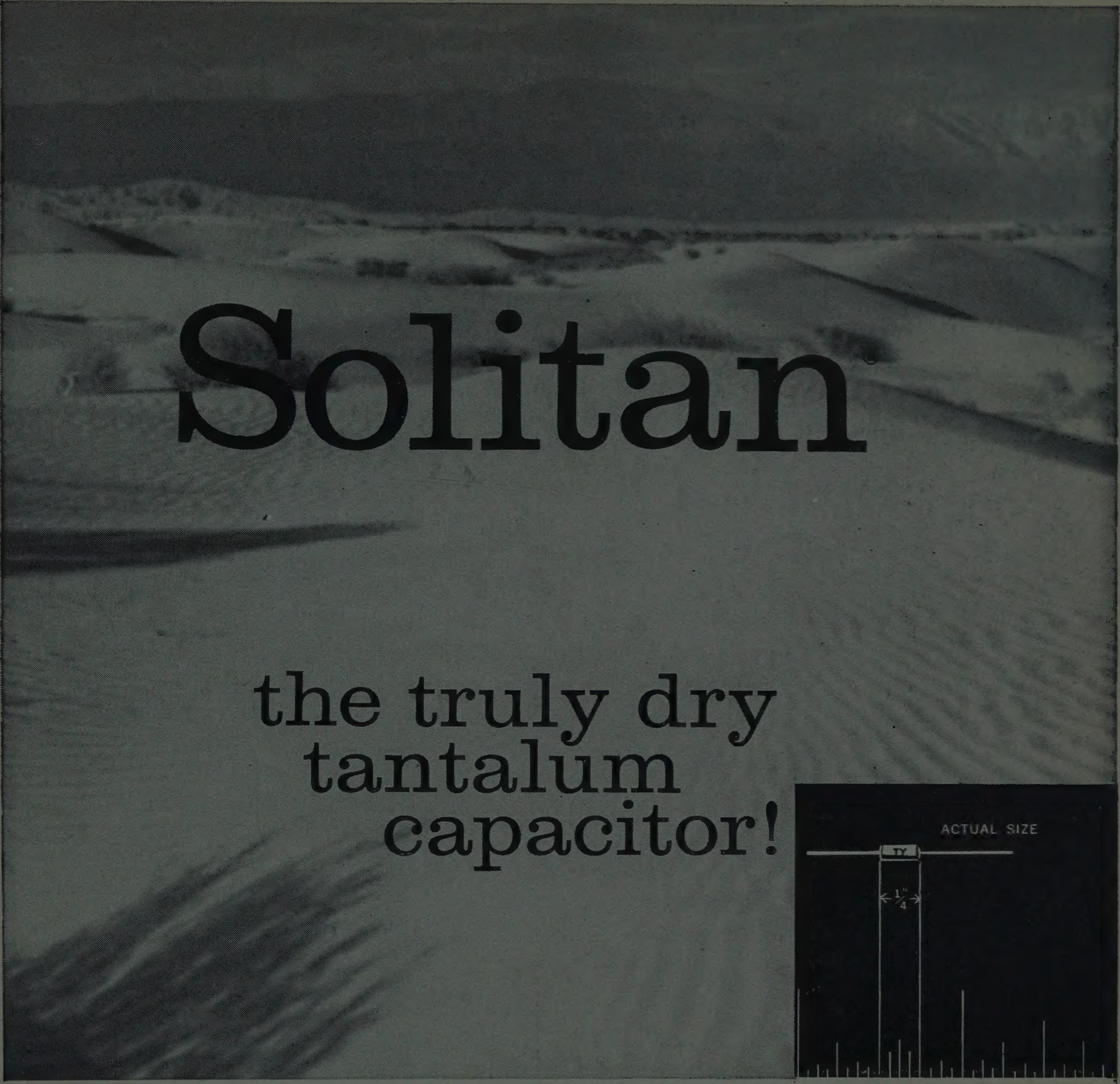
Sage Electronics Corp. 44A
Sanborn Company 35A
Sanders Associates, Inc. 148A
Sangamo Electric Co. 79A
Scientific-Atlanta, Inc. 106A
Sensitive Research Instrument Corp. 28A
Singer Manufacturing Co. 113A
Sola Electric Company 105A
Southwestern Industrial Electronics Co. 44A
Specific Products 92A
Sperry Electronic Tube Div., Sperry Rand Corp. 134A
Sperry Gyroscope Co., Div. Sperry Rand Corp. 115A
Spittal, William R. 162A
Sprague Electric Co. 3A, 5A
Stanford Research Institute 152A
Stavid Engineering, Inc. 146A
Stoddart Aircraft Radio Co., Inc. 162A
Stromberg-Carlson Company 78A, 151A
Swift Textile Metalizing & Laminating Corp. 48A
Switchcraft, Inc. 98A
Sylvania Electric Products Inc. ..101A, 126A, 127A
Systems, Incorporated 132A

Tarzian, Inc., Sarkes 62A
Tektronix, Inc. 68A
Telecomputing Corp. 43A
Temco Aircraft Corporation 71A
Texas Instruments Incorporated 19A, 38A-39A, 142A
Thompson-Ramo-Wooldridge Products Co. ..152A
Transitron Electronic Corp. 49A
Triad Transformer Corp. 10A
Tung-Sol Electric, Inc. 63A, 91A

Union Switch & Signal Div. 85A
United States Air Force 141A
United Transformer Corp. ....Cover 2

Varian Associates 70A
Victory Engineering Corp. 110A
Vitro Laboratories 114A

Wallace, Don C. 162A
Ward Leonard Electric Co. 93A
Washington Aluminum Co., Inc. 74A
Waterman Products Co., Inc. 52A
Wayne Kerr Corporation 90A
Welwyn International, Inc. 164A
Weston Electrical Instrument Corp. 75A
Wheeler, Harold A. 162A
White Dental Mfg. Co., S. S. 78A



NEW SOLID-STATE ELECTROLYTE CAPACITORS BY CORNELL-DUBILIER • SOLITAN capacitors are specifically designed for transistor application in computer and military circuits. Solid electrolyte tantalum assures extreme resistance to shock and vibration, wider useful temperature characteristics, stability of capacitance in spite of aging or temperature variations, freedom from corrosion or leakage. Cornell-Dubilier has SOLITAN tantalum capacitors in production quantities. Write for 4-pg. Bulletin No. 537 to Dept. IR-8, Cornell-Dubilier Electric Corp., South Plainfield, N.J.

SOLITAN

Specifications and Features

- Ratings up to 6.0 mfd. at 35 volts DC Working, or 60.0 mfd. at 6 volts
- Wider useful temperature characteristics within range of −80°C to +85°C
- Freedom from corrosion and leakage
- Extremely small size
- Remarkable stability of capacitance with time and temperature
- Metal cased, hermetically sealed

Consistently Dependable

CORNELL-DUBILIER

CAPACITORS

now microwave standard frequencies

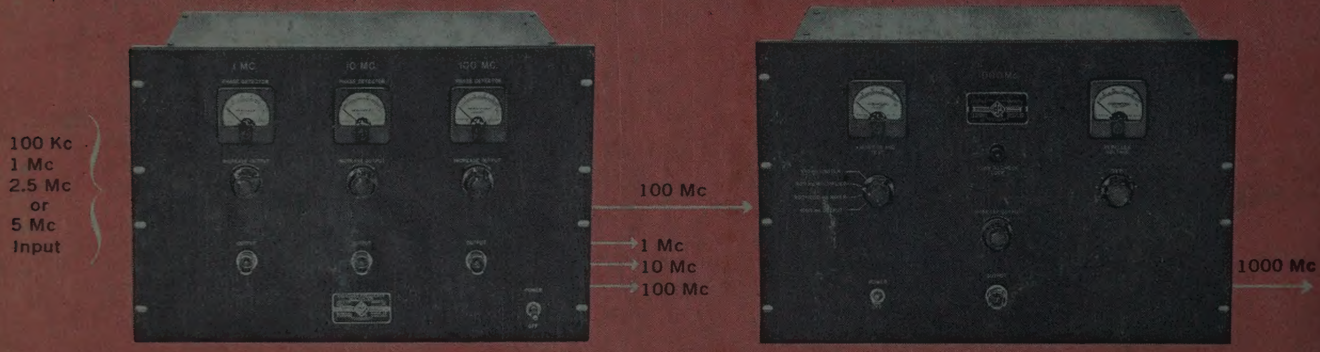
from NEW GR® DECADE MULTIPLIERS

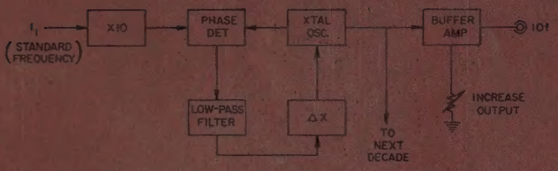
Two new Standard Frequency Multipliers, the Types 1112-A and 1112-B, extend the range of General Radio's line of frequency-measuring equipment to well beyond the X band.

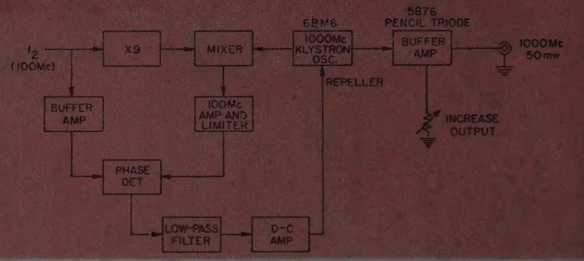
Extremely low noise characteristics and high stability, primary objectives in the development of these instruments, permit their use for precise measuring applications. Telemetering, missile tracking, spectroscopy and atomic-resonance investigations, radar and navigation-systems work are but a few of the areas where signals of this quality are needed.

Submultiples of output frequencies are missing—all spurious r-f and sideband signals are more than 100db below the nominal output signal. Long-term frequency stability is dependent only upon the driving source. Short-term stability is actually so much better than that of other types of frequency multipliers that measurement of performance is difficult — data will be available later.

The new Multipliers are versatile and convenient in use: for example, accurate measurements of microwave frequencies may be made by using a simple distorting and mixing diode to produce higher frequency harmonics for comparison against an unknown signal. For such work, a "picket fence" of standard-frequency markers can be generated (with suitable adding network), against which the unknown can be located quickly, unambiguously, and accurately.







Type 1112-A Standard Frequency Multiplier

1-Mc, 10-Mc, and 100-Mc output frequencies are generated by separate *crystal* oscillators that are *phase locked* to the input frequency to insure extremely low f-m and a-m noise levels. (See diagram for typical decade.) Use of quartz-crystal resonators in each of these oscillators provides the highest possible Q for stabilizing amplitude and phase. With this technique, it is possible to avoid much of the noise commonly associated with multipliers that do not have such high-Q filters, and consequently, to actually improve the S/N ratio of the output signal.

INPUT: 1-volt, 100-kc sine wave from G-R Type 1100-A Frequency Standard or equivalent. Can be driven by 1-Mc, 2.5-Mc, or 5-Mc standard-frequency signal as well.

OUTPUT: 1-Mc, 10-Mc, and 100-Mc sine-wave signals; output level of each independently adjustable with maximum of 20mw into 50 ohms.

STABILITY: Long-term stability dependent only upon driving source.

PRICE: $1450.

Type 1112-B Standard Frequency Multiplier

1000-Mc output is generated directly by a 6BM6 klystron that is phase-locked to the 100-Mc input. Input is multiplied to 900 Mc and mixed with the 1000-Mc output from the klystron oscillator to produce a 100-Mc beat. The difference frequency is amplified and limited to reduce a-m noise, and then compared to the 100-Mc input in a balanced phase detector. The output from the phase detector controls klystron frequency by varying repeller voltage. Phase-modulated noise normally produced by a klystron is greatly reduced by a wide-band, or fast-acting automatic-phase control.

INPUT: 100-Mc sine wave from Type 1112-A or equivalent; input impedance is 50 ohms.

OUTPUT: 1000-Mc sine wave; at least 50mw into 50-ohm load.

STABILITY: Long-term stability dependent only upon driving source.

PRICE: $1360.

Write for Complete Information on G-R Frequency Standards.

GENERAL RADIO Company

275 Massachusetts Avenue, Cambridge 39, Mass., U. S. A.

GR 2-Year Warranty on every Product

NEW YORK AREA: Tel. N. Y. WOrth 4-2722, N. J. WHitney 3-3140 **CHICAGO:** Tel. Village 8-9400
PHILADELPHIA: Tel. HAncock 4-7419 **WASHINGTON, D. C.:** Tel. JUniper 5-1088
SAN FRANCISCO: Tel. WHitecliff 8-8233 **LOS ANGELES 38:** Tel. HOllywood 9-6201
In CANADA, TORONTO: Tel. CHerry 6-2171

WE SELL DIRECT. Our District Sales Offices are staffed by engineers especially trained to help you in the selection of instruments and measuring systems best suited to your needs. We welcome your inquiries — will help solve your problems.